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Basalt Mineral Tracers to Determine Road Sediment Sources

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"Basalt Mineral Tracers to Determine Road Sediment Sources"
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Basalt Mineral Tracers to Determine Road Sediment Sources:

Final Report

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Endmember sediment samples (road rock and cutslope material) were shatterboxed and analyzed using the Rigaku Miniflex X-ray Defractometer (XRD). Sample identifications and sample descriptions can be found in Table 1. Several peaks were identified for each endmember composition[1]. Plagioclase peaks for the road rock samples were found at 2-theta = 21.9 and at 2-theta = 27.79. Quartz peaks were found for the cutslope materials at 2-theta = 20.85 and 2-theta = 26.68. X-ray diffraction patterns are included in Appendix A.

The endmember compositions were mixed in known ratios and these samples were analyzed with the XRD. These data are included in Table 2 and X-ray diffraction patterns are included in Appendix C. Measurements of the areas under the peaks of interest were made using a modified version of an AUTOCAD drafting routine by Dr. Cliff Ambers. Ratios were calculated of the areas under the peaks identified for road rock samples to the area under the peaks identified for cutslope materials. Figure 1 shows the relationship between the percent road rock, as measured, and the ratio of the areas under the peaks. The strongest relationship between percent road rock and the ratio of the peak areas was found for the peaks at 2-theta = 21.9 (plagioclase) for the road rock and 2-theta = 26.68 (quartz) for the cutslope material. Samples from the flume experiments were also analyzed and there did not appear to be substantial compositional variation between the flume samples and the endmember samples. The X-ray diffraction patterns for the flume samples are shown in Appendix B.

[1] Peaks were identified with data from *Table of Key Lines in X-ray Powder Diffraction Patterns of Minerals in Clays and Associated Rocks* by Pei-Yuan Chen (Department of Natural Resources Geological Survey Occasional Paper 21, 1977).

In order to better characterize the relationship between the areas under the peaks and the percent road rock in the sample, we analyzed known mixtures of the two endmember compositions for 0%, 5%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, and 100% road rock. Each mixture was run a total of three times in order to account for any variability between the individual samples. These data are shown in Table 2 and Figure 2. We determined that the relationship between the percent road rock and the ratio of the areas under the peaks is an exponential relationship and is given by the equation $y= 0.0534e^{0.0393x}$ where y is the ratio of the areas under the peaks and x is the percent road rock. Individual samples exhibit a large degree of variability in the measurement of the area under the peaks, though there is still relatively good agreement between the actual measured percent road rock and the amount of road rock calculated from the determination of the area under the peaks (Figure 3). However, road rock is not detectable below 20% of the composition of the sample.

We also analyzed the areas under the peaks at 2-theta = 27.7 and 2-theta=20.9 with the aim of finding a relationship that is discernible below 20% road rock. There is a reasonably strong correlation between the ratio of areas under the peaks and the measured amount of road rock (R^2=0.7552, Figure 4). The relationship is given by the equation $y=0.4003e^{0.0546x}$ where y is the ratio of peak areas and x is the actual percent road rock. The relationship does not hold, however, above 60 percent road rock (Figure 2).

Flume samples were also mixed in known proportions with compositions of 0%, 20%, 40%, 60%, 80%, and 100% road rock. Each sample was run a total of three times. These data are shown in Table 2 and the X-ray diffraction patterns are shown in Appendix D. The ratio of the areas under the quartz and plagioclase peaks were

determined. The relationship between the percent road rock and the ratio of the areas for the flume experiments is shown in Figure 2. The relationship is similar to the one determined for endmembers (peaks at 2-theta of 21.9 and 26.6), but there is detectable quartz in the samples that are 100% road rock. The equation that best describes the relationship is given by the equation $y=0.0516e^{0.0338x}$ where y is the ratio of the areas under the peaks and x is the percent road rock. The agreement between the measured and the calculated percentage of road rock is not as good as that for the endmember compositions (Figure 5).

Unknown samples were shatterboxed and analyzed with the XRD. The area under the plagioclase and quartz peaks were measured using AUTOCAD. These data are shown in Table 3 and the X-ray diffraction patterns are shown in Appendix E. The percent road rock in each sample was calculated using the relationships determined above for both the flume and the endmember samples (Table 3).

Another method of determining the percent road rock of the samples was also tested. Density measurements were made of the road rock and cutslope materials using a technique modified from Klein and Hurlbut (1993)[2]. The method employed is also similar to the Pyncometer method of Blake and Hartge (1986)[3], however, boiling was not used as a means of removing air bubbles for this first approximation. The presence of trapped air is one possible source of error in these density measurement. Preliminary

[2] Klein, Cornelis, and Cornelius S. Hurlbut, Jr. *Manual of Mineralogy*. John Wiley and Son, Inc., New York: 1993.

[3] Blake, G.R. and K.H. Hartge. 1986. *Particle Density*, In: Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods - Agronomy Monograph no 9. (2nd addition).

measurements of the densities of the endmember samples showed that there is a substantial difference in density between the road and cutslope compositions.

Measurements were made by first weighing a 250 ml eryhlenmeyer flask and a glass stopper. The flask containing the dry sample and air was weighed next (W_a). The flask containing the sample was then filled with water to the top of the glass stopper and then re-weighed (W_w). The density of the rock can be determined from the difference in the mass of the sample in water and the known volume of the flask containing only water. In order to make a precise density measurement, the volume of water contained within the flask and stopper must be known precisely. When the flask is full, it holds 250 ml of water. The hollow stopper can hold an additional 14.8 ml of water as determined by adding water to the stoppered flask with a graduated syringe. Thus, the total volume of water that can be contained within the flask and stopper is 254.8 ml (V_t). The temperature of tap water in the laboratory was determined to be 21.2 °C. The density of water at this temperature is 0.997944 g/cc (D_w). The density of the solid sample is thus given by the following equation:

$$\text{Density} = \frac{W_a}{V_t - \left[\frac{W_W - W_a}{D_W}\right]}$$

Ten density measurements of the road rock and cutslope endmembers were made (Table 4). The road rock material had a mean density of 2.7 g/cc whereas the cutslope material had a mean density of 2.0 g/cc. The two endmembers were mixed in known proportions and the densities were measured. There was good agreement between the

measured and calculated percent road rock (Table 5 and Figure 6). However, the road rock flume samples had lower densities than the road rock endmembers (Table 6), perhaps because there is addition of quartz to the road rock flume samples (determined from XRD). The cutslope flume samples were similar to the cutslope endmembers in terms of their densities.

The densities of the unknowns were determined using the same procedure as for the endmembers (Table 7). There is poor agreement between the percent road rock determined from XRD and the percent road rock determined from the density measurements (Table 7). We may retry the density measurements following the procedures of Blake and Hartge.

The shatterboxed endmembers, when mixed in known proportions show a remarkable gradation in color from a dark gray (100% road rock) to a reddish-brown (0 % road rock). Color could potentially be another possible way to estimate the percent road rock in each unknown sample. The color of the shatterboxed unknown samples was compared with the colors of known mixed samples (0-100% road rock). The percent road rock was estimated based on the color scale. These data are also shown in Table 7.

Table 1: Sample descriptions

Sample ID	Sample description
known mixtures	
rd134l	plot 134 lower road rock
rd134m	plot 134 middle road rock
run1	plot 134 upper road rock
134b	plot 134 upper road rock (second run)
134c	plot 134 upper road rock (third run)
sl134l	plot 134 lower cutslope
sl134m	plot 134 middle cutslope
sl134u	plot 134 upper cutslope
5_134u	5% plot 134 upper road rock, 95% plot 134 upper cutslope
b5_134u	5% plot 134 upper road rock, 95% plot 134 upper cutslope (second run)
c5_134u	5% plot 134 upper road rock, 95% plot 134 upper cutslope (third run)
10_134u	10% plot 134 upper road rock, 90% plot 134 upper cutslope
b10_134u	10% plot 134 upper road rock, 90% plot 134 upper cutslope (second run)
c10_134u	10% plot 134 upper road rock, 90% plot 134 upper cutslope (third run)
20_134u	20% plot 134 upper road rock, 80% plot 134 upper cutslope
b20_134u	20% plot 134 upper road rock, 80% plot 134 upper cutslope (second run)
c20-134u	20% plot 134 upper road rock, 80% plot 134 upper cutslope (third run)
30_134u	30% plot 134 upper road rock, 70% plot 134 upper cutslope
b30_134u	30% plot 134 upper road rock, 70% plot 134 upper cutslope (second run)
c30_134u	30% plot 134 upper road rock, 70% plot 134 upper cutslope (third run)
40_134u	40% plot 134 upper road rock, 60% plot 134 upper cutslope
b40_134u	40% plot 134 upper road rock, 60% plot 134 upper cutslope (second run)
c40_134u	40% plot 134 upper road rock, 60% plot 134 upper cutslope (third run)
50_134u	50% plot 134 upper road rock, 50% plot 134 upper cutslope
b50_134u	50% plot 134 upper road rock, 50% plot 134 upper cutslope (second run)
c50_134u	50% plot 134 upper road rock, 50% plot 134 upper cutslope (third run)
60_134u	60% plot 134 upper road rock, 40% plot 134 upper cutslope
b60_134u	60% plot 134 upper road rock, 40% plot 134 upper cutslope (second run)
c60_134u	60% plot 134 upper road rock, 40% plot 134 upper cutslope (third run)
70_134u	70% plot 134 upper road rock, 30% plot 134 upper cutslope
b70_134u	70% plot 134 upper road rock, 30% plot 134 upper cutslope (second run)
c70_134u	70% plot 134 upper road rock, 70% plot 134 upper cutslope (third run)
80_134u	80% plot 134 upper road rock, 20% plot 134 upper cutslope
b80_134u	80% plot 134 upper road rock, 20% plot 134 upper cutslope (second run)
c80_134u	80% plot 134 upper road rock, 20% plot 134 upper cutslope (third run)
90_134u	90% plot 134 upper road rock, 10% plot 134 upper cutslope
b90_134u	90% plot 134 upper road rock, 10% plot 134 upper cutslope (second run)
c90_134u	90% plot 134 upper road rock, 10% plot 134 upper cutslope (third run)
95_134u	95% plot 134 upper road rock, 5% plot 134 upper cutslope
b95_134u	95% plot 134 upper road rock, 5% plot 134 upper cutslope (second run)
c95_134u	95% plot 134 upper road rock, 5% plot 134 upper cutslope (third run)
134flume	road rock effluent plot 134 flume test
bflumrd	road rock effluent plot 134 flume test (second run)
cflumrd	road rock effluent plot 134 flume test (third run)

Table 1: Sample descriptions

Sample ID	Sample description
113flume	road rock effluent plot 113 flume test
80flum	80% road rock effluent plot 134 flume test, 20% cutslope plot 134 flume test
b80flum	80% road rock effluent plot 134 flume test, 20% cutslope plot 134 flume test (second run)
c80flum	80% road rock effluent plot 134 flume test, 20% cutslope plot 134 flume test (third run)
60flum	60% road rock effluent plot 134 flume test, 40% cutslope plot 134 flume test
b60flum	60% road rock effluent plot 134 flume test, 40% cutslope plot 134 flume test (second run)
c60flum	60% road rock effluent plot 134 flume test, 40% cutslope plot 134 flume test (third run)
40flum	40% road rock effluent plot 134 flume test, 60% cutslope plot 134 flume test
b40flum	40% road rock effluent plot 134 flume test, 60% cutslope plot 134 flume test (second run)
c40flum	40% road rock effluent plot 134 flume test, 60% cutslope plot 134 flume test (third run)
20flum	20% road rock effluent plot 134 flume test, 80% cutslope plot 134 flume test
b20flum	20% road rock effluent plot 134 flume test, 80% cutslope plot 134 flume test (second run)
c20flum	20% rod rock effluent plot 134 flume test, 80% cutslope plot 134 flume test (third run)
flumesl	cutslope plot 134 flume test
bflusl	cutslope plot 134 flume test (second run)
cflumsl	cutslope plot 134 flume test (third run)
unknowns	
10371299	LP 103 7/12/99 sediment tank grab sample
11871499	LP 118 7/14/99 sediment tank grab sample
13312797	LP 133 1/27/97 road plot sediment tank grab sample
13481299	plot 134 8/12/99 sediment tank grab sample
123_6199	LP 123 6/1/99 sediment tank grab sample
17_22196	LP 17 2/21/96
17_7897	LP 17 7/8/97
17a62496	LP 17 6/24/96 (a)
17b62496	LP 17 6/24/96 (b)
23_21596	23 box grab 2/15/96
23_61097	LP 23 6/10/97
23_62596	LP 23 6/25/96
28_296	28 2/96
28_62596	LP 28 6/25/96
28_72297	LP 28 7/22/97
3_22796	LP 3 2/27/96
3_62196	LP 3 6/21/96
3_62697	LP 3 6/26/97
3_72897	LP 3 7/28/97
3_73098	LP 3 7/30/98
39_12797	LP 39 1/27/97
39_2896	39 2/8/96
39_62696	LP 39 6/26/96
39_72497	LP 39 7/24/97

Table 2: XRD data for endmember and flume experiments

sample	% road rock (meas.)	% cut-slope (meas.	peak area 2T=26.6	peak area 2T=21.9	ratio areas (21.9/26.6)	peak area 2T=27.7	peak area 2T=20.9	ratio areas (27.7/20.9)	% road (calc. 21.9/26.6 endmem.)	% road (calc. 27.7/20.9 endmem.)	% road (calc. flume)
rd134l	100	0	0	43.2256	NA	180.7463	0	NA	NA	NA	NA
rd134m	100	0	0	62.7093	NA	128.9434	0	NA	NA	NA	NA
run1	100	0	0	62.965	NA	202.6023	0	NA	NA	NA	NA
134b	100	0	0	50.0991	NA	301.0236	0	NA	NA	NA	NA
134c	100	0	0	58.3867	NA	181.2326	0	NA	NA	NA	NA
sl134l	0	100	193.1252	0	0	0	40.0055	0	NA	NA	NA
sl134m	0	100	154.0992	0	0	0	31.3732	0	NA	NA	NA
sl134u	0	100	167.0336	0	0	0	35.4446	0	NA	NA	NA
5_134u	5	95	178.9845	0	0	9.3514	21.7065	0.430811047	NA	1.3	NA
b5_134u	5	95	159.243	0	0	25.6549	21.7575	1.179129036	NA	19.8	NA
c5_134u	5	95	142.3576	0	0	8.1883	31.9625	0.256184591	NA	-8.2	NA
10_134u	10	90	102.4191	0	0	10.6551	28.2722	0.376875517	NA	-1.1	NA
b10_134u	10	90	115.7875	0	0	9.0609	19.6647	0.460769806	NA	2.6	NA
c10_134u	10	90	187.5851	0	0	10.9821	22.4886	0.488340759	NA	3.6	NA
20_134u	20	80	107.8472	23.4621	0.217549459	90.4729	23.0337	3.927849195	35.7	41.8	42.6
b20_134u	20	80	201.7641	14.3929	0.071335287	35.2369	17.1823	2.050767359	7.4	29.9	9.6
c20-134u	20	80	142.4823	15.9872	0.112204814	38.5745	18.732	2.059283579	18.9	30.0	23.0
30_134u	30	70	106.6014	16.6879	0.156544848	15.9853	11.7496	1.360497379	27.4	22.4	32.8
b30_134u	30	70	142.2717	26.4253	0.185738274	43.0046	10.5939	4.059373791	31.7	42.4	37.9
c30_134u	30	70	102.5383	16.7536	0.163388705	47.7557	33.0401	1.445386061	28.5	23.5	34.1
40_134u	40	60	88.3494	31.9384	0.36150104	51.7961	10.9773	4.718473577	48.7	45.2	57.6
b40_134u	40	60	60.3046	24.6019	0.407960587	34.0729	15.2675	2.231727526	51.7	31.5	61.2
c40_134u	40	60	89.1715	13.0467	0.1463102	60.0161	24.2221	2.477741401	25.6	33.4	30.8
50_134u	50	50	77.6418	28.9828	0.373288615	70.7995	20.1354	3.516170526	49.5	39.8	58.5
b50_134u	50	50	80.7952	36.1523	0.447456037	77.1958	9.6104	8.032527262	54.1	54.9	63.9
c50_134u	50	50	54.0375	21.726	0.402054129	72.0645	12.5763	5.730182963	51.4	48.7	60.7
60_134u	60	40	53.0695	39.7704	0.749402199	179.526	14.1561	12.68188272	67.2	63.3	79.2
b60_134u	60	40	71.7459	30.7729	0.428915102	104.8491	0	NA	53.0	NA	62.7
c60_134u	60	40	57.3691	32.5119	0.566714486	127.1587	0	NA	60.1	NA	70.9
70_134u	70	30	56.9622	32.5676	0.571740558	85.24	0	NA	60.3	NA	71.2
b70_134u	70	30	69.7844	45.9042	0.657800311	102.7925	0	NA	63.9	NA	75.3

Table 2: XRD data for endmember and flume experiments

sample	% road rock (meas.)	% cut-slope (meas.	peak area 2T=26.6	peak area 2T=21.9	ratio areas (21.9/26.6)	peak area 2T=27.7	peak area 2T=20.9	ratio areas (27.7/20.9)	% road (calc. 21.9/26.6 endmem.)	% road (calc. 27.7/20.9 endmem.)	% road (calc. flume)
c70_134u	70	30	58.9806	52.1129	0.883560018	104.7309	0	NA	71.4	NA	84.0
80_134u	80	20	38.4612	42.9312	1.116221023	170.0535	0	NA	77.4	NA	91.0
b80_134u	80	20	30.705	46.252	1.506334473	109.4804	0	NA	85.0	NA	99.8
c80_134u	80	20	42.8856	38.7495	0.903555039	120.6028	0	NA	72.0	NA	84.7
90_134u	90	10	30.7531	56.3946	1.833785862	133.6354	0	NA	90.0	NA	105.6
b90_134u	90	10	35.6115	40.7345	1.143858023	27.7952	0	NA	78.0	NA	91.7
c90_134u	90	10	35.2073	53.8556	1.529671403	154.4831	0	NA	85.4	NA	100.3
95_134u	95	5	12.381	43.6747	3.527558356	195.9924	0	NA	106.6	NA	125.0
b95_134u	95	5	15.0417	46.0236	3.05973394	204.2612	0	NA	103.0	NA	120.8
c95_134u	95	5	19.626	58.2613	2.968577397	136.5612	0	NA	102.2	NA	119.9
134flume	100	0	29.9209	44.4529	1.485680578	191.3811	0	NA	84.6	NA	99.4
bflumrd	100	0	24.4637	46.5232	1.901723778	122.0606	0	NA	90.9	NA	106.7
cflumrd	100	0	24.6658	33.5008	1.358188261	82.0367	0	NA	82.3	NA	96.8
113flume	100	0	39.3814	55.4828	1.408857989	146.7084	0	NA	83.3	NA	97.8
80flum	80	20	43.4498	32.4589	0.747043715	46.4275	7.3559	6.311600212	67.1	50.5	79.1
b80flum	80	20	85.8094	48.2615	0.562426727	66.4029	0	NA	59.9	NA	70.7
c80flum	80	20	40.9379	37.7474	0.922064884	74.4537	0	NA	72.5	NA	85.3
60flum	60	40	82.1664	30.4571	0.370675848	86.5392	20.0591	4.314211505	49.3	43.5	58.3
b60flum	60	40	67.7622	25.9089	0.382350337	64.6043	23.3809	2.763122891	50.1	35.4	59.3
c60flum	60	40	64.748	25.3473	0.391476185	56.7627	13.1158	4.327810732	50.7	43.6	60.0
40flum	40	60	96.5991	25.0344	0.259157694	44.6218	13.4513	3.317285318	40.2	38.7	47.7
b40flum	40	60	86.0507	21.6484	0.251577268	39.987	16.1083	2.482384857	39.4	33.4	46.9
c40flum	40	60	97.3448	22.0377	0.226388056	39.7148	15.5623	2.551987817	36.8	33.9	43.7
20flum	20	80	136.9649	9.8744	0.072094383	18.5503	19.3162	0.960349344	7.6	16.0	9.9
b20flum	20	80	112.1089	26.8732	0.239706214	28.8832	19.3274	1.494417252	38.2	24.1	45.4
c20flum	20	80	124.6481	5.1803	0.041559398	32.2166	18.3028	1.760200625	-6.4	27.1	-6.4
flumesl	0	100	159.8279	0	0	0	44.0872	0	NA	NA	NA
bflusl	0	100	191.3859	0	0	0	33.454	0	NA	NA	NA
cflumsl	0	100	217.9945	0	0	0	30.6749	0	NA	NA	NA

Table 3: XRD data for unknowns

sample	peak area 2T=26.6	peak area 2T=21.9	ratio areas (21.9/26.6)	peak area 2T=27.7	peak area 2T=20.9	ratio areas (27.7/20.9)	% road rock (calc. 21.9/26.6 endmemb.)	% road rock (calc. 27.7/20.9 endmemb.)	% road rock (calculated from flume)
3_62697	17.7677	61.7662	3.4763194	72.5763	0	NA	106.3	>60	124.6
3_72897	78.5491	28.9636	0.3687324	51.6306	12.0224	4.2945335	49.2	43.5	58.2
3_73098	17.4059	44.617	2.5633262	120.6833	0	NA	98.5	>60	115.5
39_12797	161.4554	0	0	42.4633	26.3531	1.6113209	<20	25.5	< 20
39_2896	161.6773	0	0	0	20.9328	0	<20	>60	< 20
39_62696	134.3801	9.5785	0.0712792	0	33.3917	0	7.3	>60	9.6
39_72497	190.0072	0	0	0	29.093	0	<20	>60	< 20
28_62596	195.6082	10.32	0.0527585	14.6301	24.4335	0.5987722	-0.3	7.4	0.7
28_72297	165.7084	16.3266	0.0985261	48.14	19.9755	2.4099522	15.6	32.9	19.1
3_22796	107.6245	20.1095	0.1868487	93.3976	13.8601	6.738595	31.9	51.7	38.1
3_62196	29.1209	49.9469	1.7151565	64.0398	0	NA	88.3	>60	103.7
17_22196	179.425	0	0	69.8596	39.2401	1.7803115	<20	27.3	< 20
17_7897	120.9599	10.456	0.0864419	71.83	13.4245	5.3506648	12.3	47.5	15.3
17a62496	146.6192	7.3417	0.0500733	26.0759	28.0875	0.928381	-1.6	15.4	-0.9
17b62496	150.9327	8.0217	0.0531475	11.3486	26.1677	0.4336873	-0.1	1.5	0.9
23_21596	183.4085	0	0	7.8047	25.8998	0.3013421	<20	-5.2	< 20
23_61097	102.2679	20.7623	0.2030187	8.655	15.5591	0.5562661	34.0	6.0	40.5
23_62596	137.5216	13.8935	0.1010278	0	19.9177	0	16.2	>60	19.9
123_6199	80.1117	50.6957	0.6328127	16.7174	18.9432	0.8825014	62.9	14.5	74.2
13312797	135.2969	0	0	29.9816	39.9606	0.750279	<20	11.5	< 20
13481299	140.8612	0	0	48.6605	21.2171	2.2934567	<20	32.0	< 20
11871499	38.9968	33.3535	0.8552881	44.5524	0	NA	70.6	>60	83.1
10371299	19.1117	44.6854	2.3381175	88.3348	0	NA	96.2	>60	112.8
28_296	271.7908	0	0	8.8862	34.3257	0.2588789	<20	-8.0	< 20

Table 4: Density measurements for endmembers (plot 134 middle)

road rock	cutslope
2.74	2.00
2.71	2.00
2.70	2.00
2.71	2.02
2.71	1.99
2.70	2.01
2.77	1.96
2.71	2.02
2.65	1.79
2.61	1.96
mean = 2.7	mean = 2.0
s.d. = 0.04	s.d. = 0.06

Table 5: Density of known endmember mixtures (plot 134 middle)

% road (calculated)	% road (measured)
97	95
84	84
74	76
54	63
40	50
26	39
17	21
7	11
0	6

Table 6: Density of endmember and flume experiment samples

sample	density (g/cc)
flume experiments	
plot 113 (road)	1.95
plot 113 (road)	2.18
plot 134 (slope)	2.13
plot 134 (slope)	2.12
plot 134 (slope)	1.97
plot 134 (slope)	1.99
plot 134 (road)	2.12
plot 134 (road)	2.01
endmembers	
plot 134 lower (road)	2.62
plot 134 upper (road)	2.67
plot 134 upper (slope)	1.90
plot 134 lower (slope)	2.02

Table 7: Percent road rock determined by density measurements, XRD, and color

sample	density (g/cc)	% road rock (XRD 21.9/26.6)	% road rock (XRD 27.7/20.9.)	% road rock (density)	% road rock (color)
3_62697	2.41	106.2	>60	58.6	90-95
3_72897	1.77	49.2	43.5	-32.9	20-30
3_73098	2.34	98.5	>60	48.6	90-95
39_12797	2.14	< 20	25.5	20.0	5-10
39_2896	2.12	< 20	>60	17.1	5-10
39_62696	2.13	7.3	>60	18.6	10-20
39_72497	1.87	< 20	>60	-18.6	10-20
28_62596	2.18	-0.3	7.4	25.7	10-20
28_72297	2.15	15.6	32.9	21.4	30-40
3_22796	1.97	31.9	51.7	-4.3	40-50
3_62196	2.19	88.3	>60	27.1	80-90
17_22196	2.17	< 20	27.3	24.3	40-50
17_7897	1.66	12.3	47.5	-48.6	40-50
17a62496	2.16	-1.6	15.4	22.9	20-30
17b62496	2.11	-0.1	1.5	15.7	30-40
23_21596	2.08	< 20	-5.2	11.4	<5
23_61097	2.11	34.0	6.0	15.7	40-50
23_62596	1.95	16.2	>60	-7.1	20-30
123_6199	2.14	62.9	14.5	20.0	90-95
13312797	2.12	< 20	11.5	17.1	<5
13481299	1.84	< 20	32.0	-22.9	NA
11871499	2.14	70.6	>60	20.0	60-70
10371299	2.24	96.2	>60	34.3	90-95
28_296	2.07	< 20	-8.0	10.0	10-20

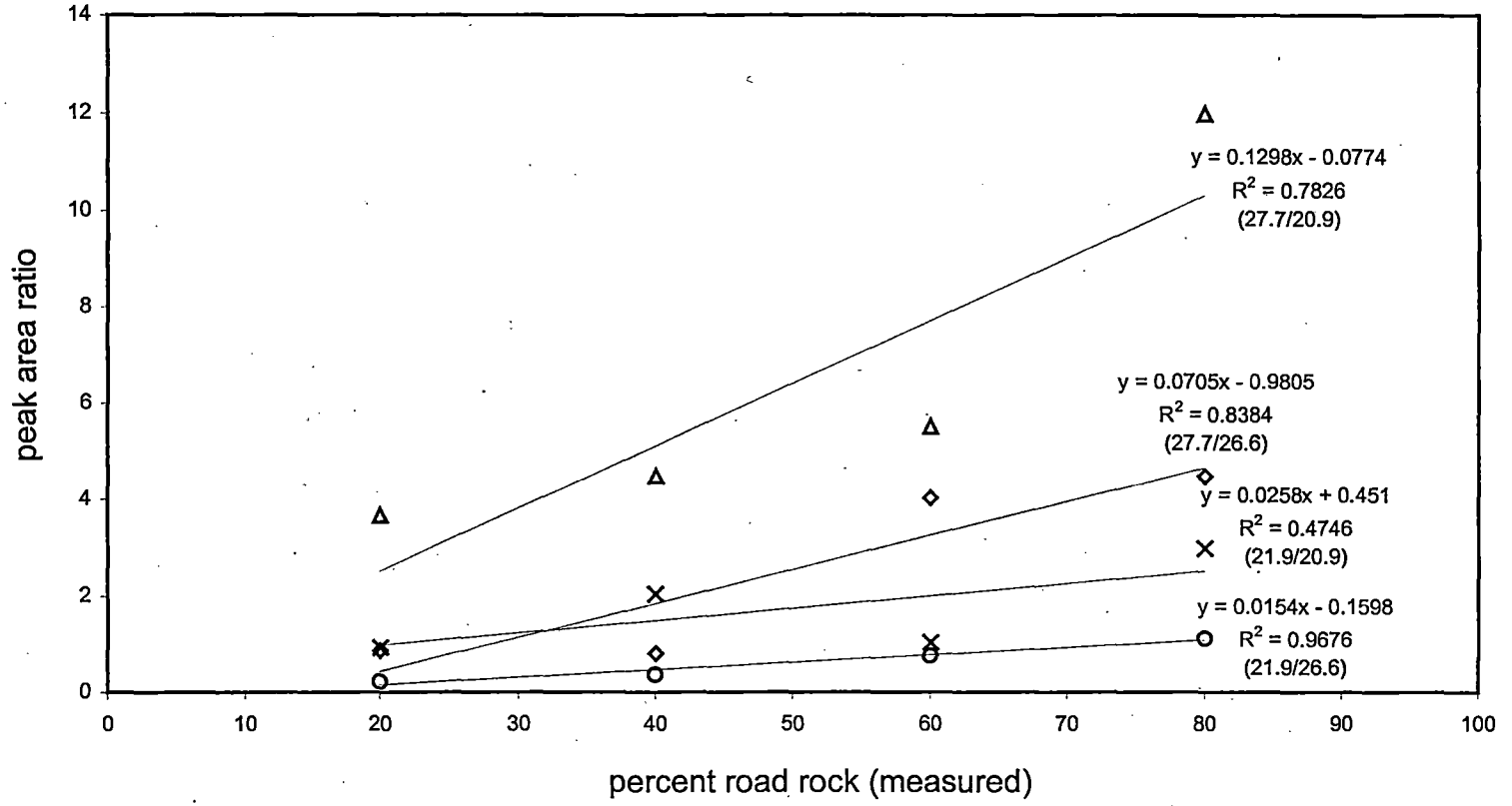


Figure 1: Relationship between the measured percent road rock and the ratio of peak areas.

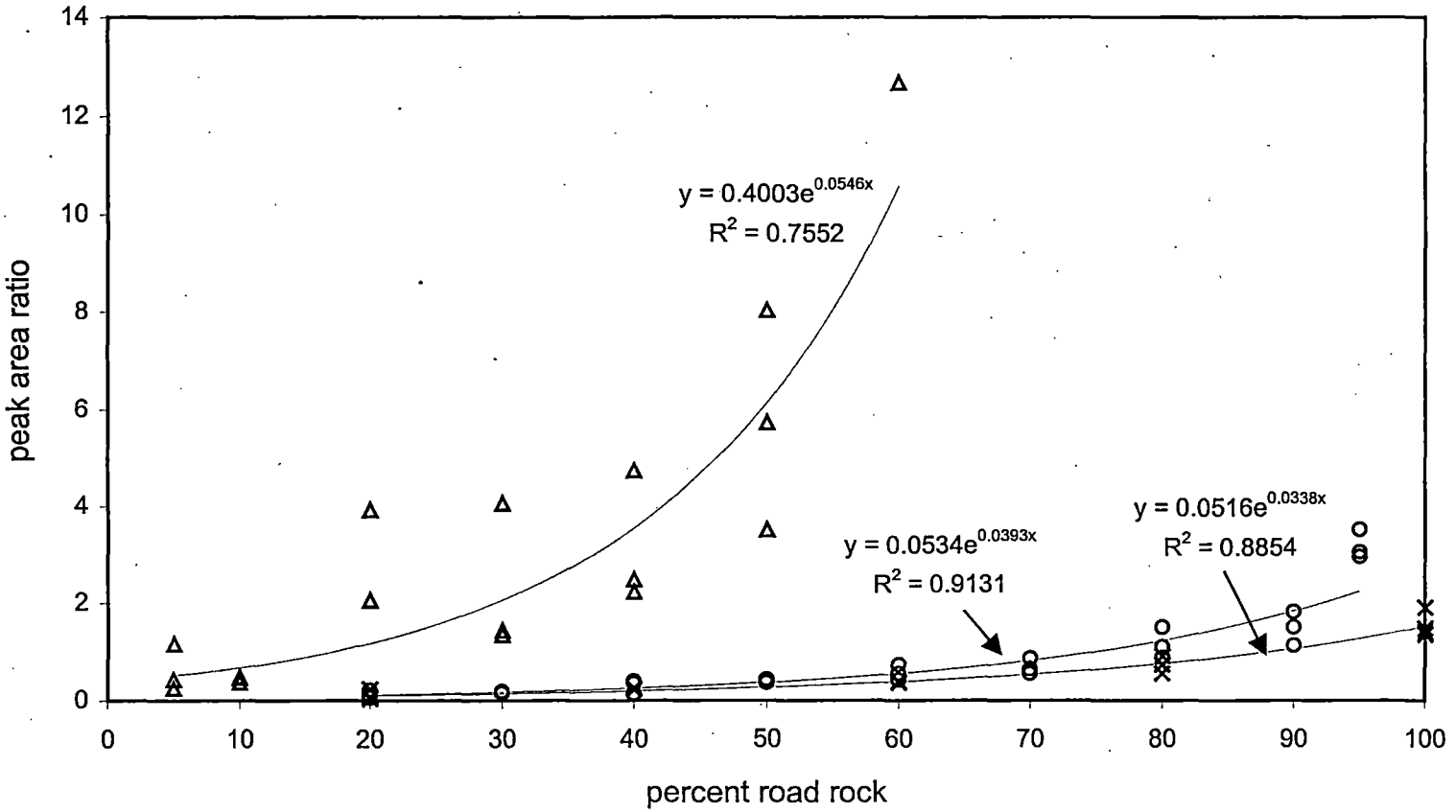


Figure 2: Known mixtures of endmember and flume experiment compositions. The x's are the flume experiments (21.9/26.6), the open circles are mixtures of the endmember road rock and cutslope material (21.9/26.6), and the open triangles are the mixtures of the endmember road rock and cutslope material (27.7/20.9).

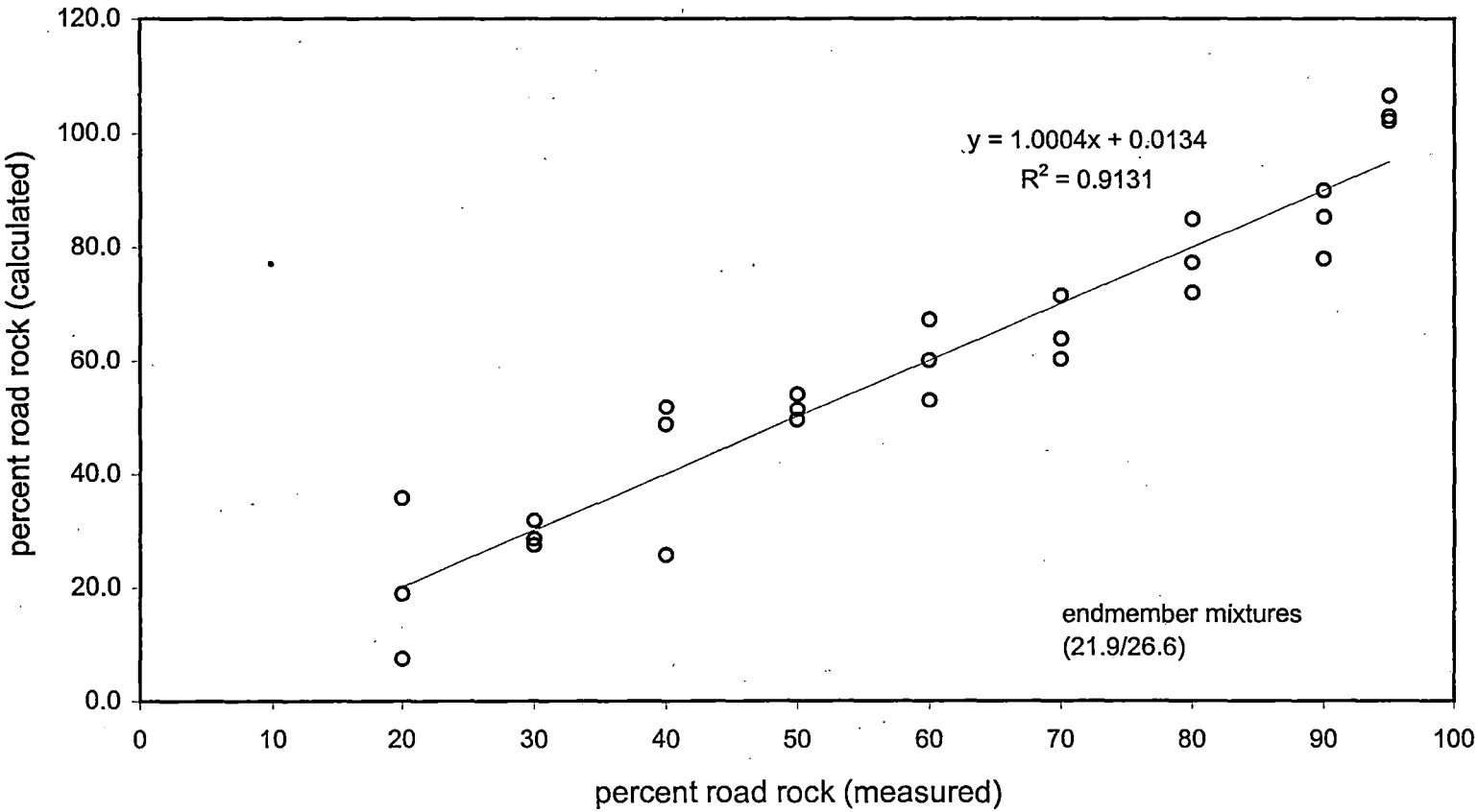


Figure 3: Known percent road rock versus the amount of road rock determined from the relationship between peak areas for the endmember compositions.

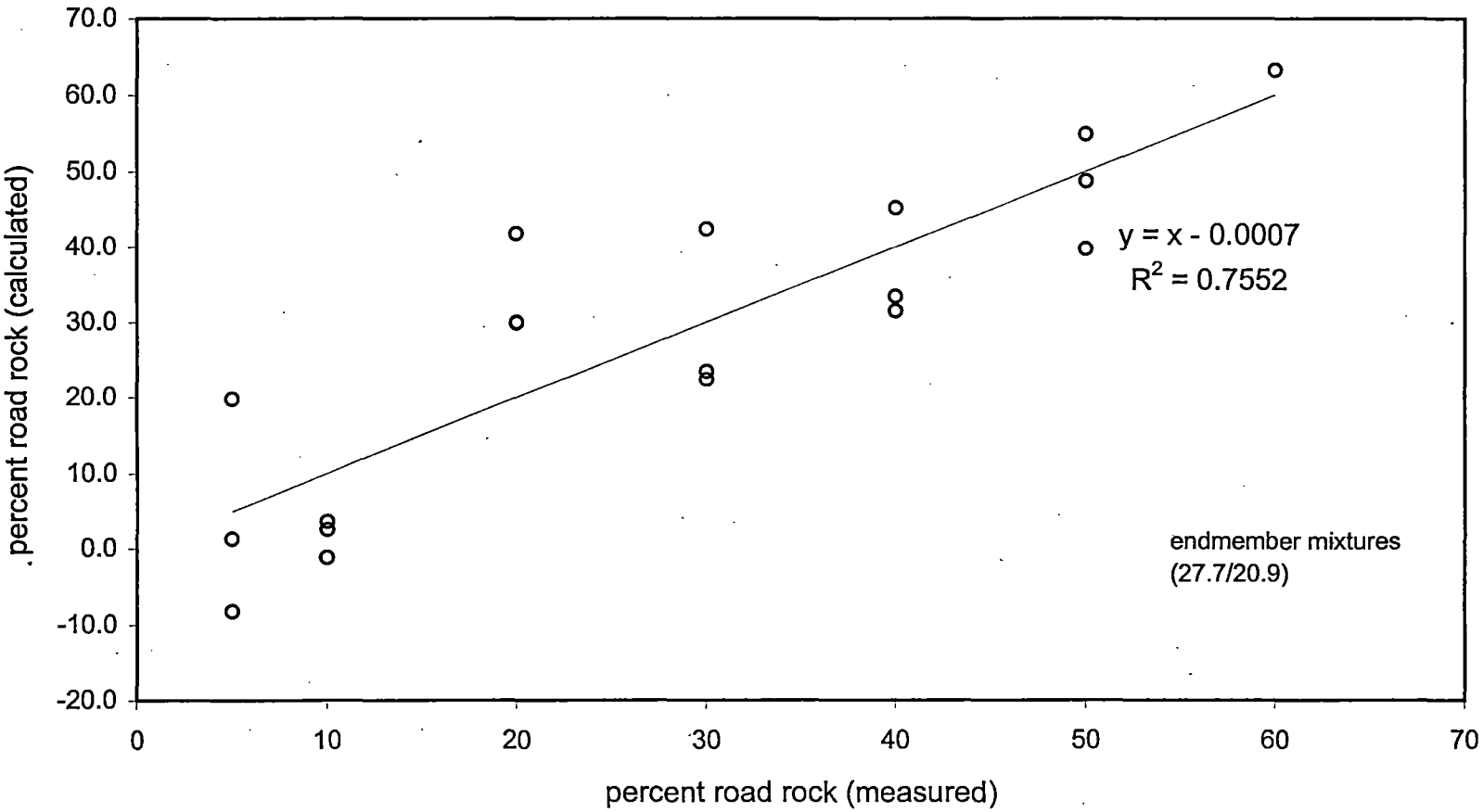


Figure 4: Known percent road rock versus the amount of road rock determined from the relationship between peak areas for the endmember compositions.

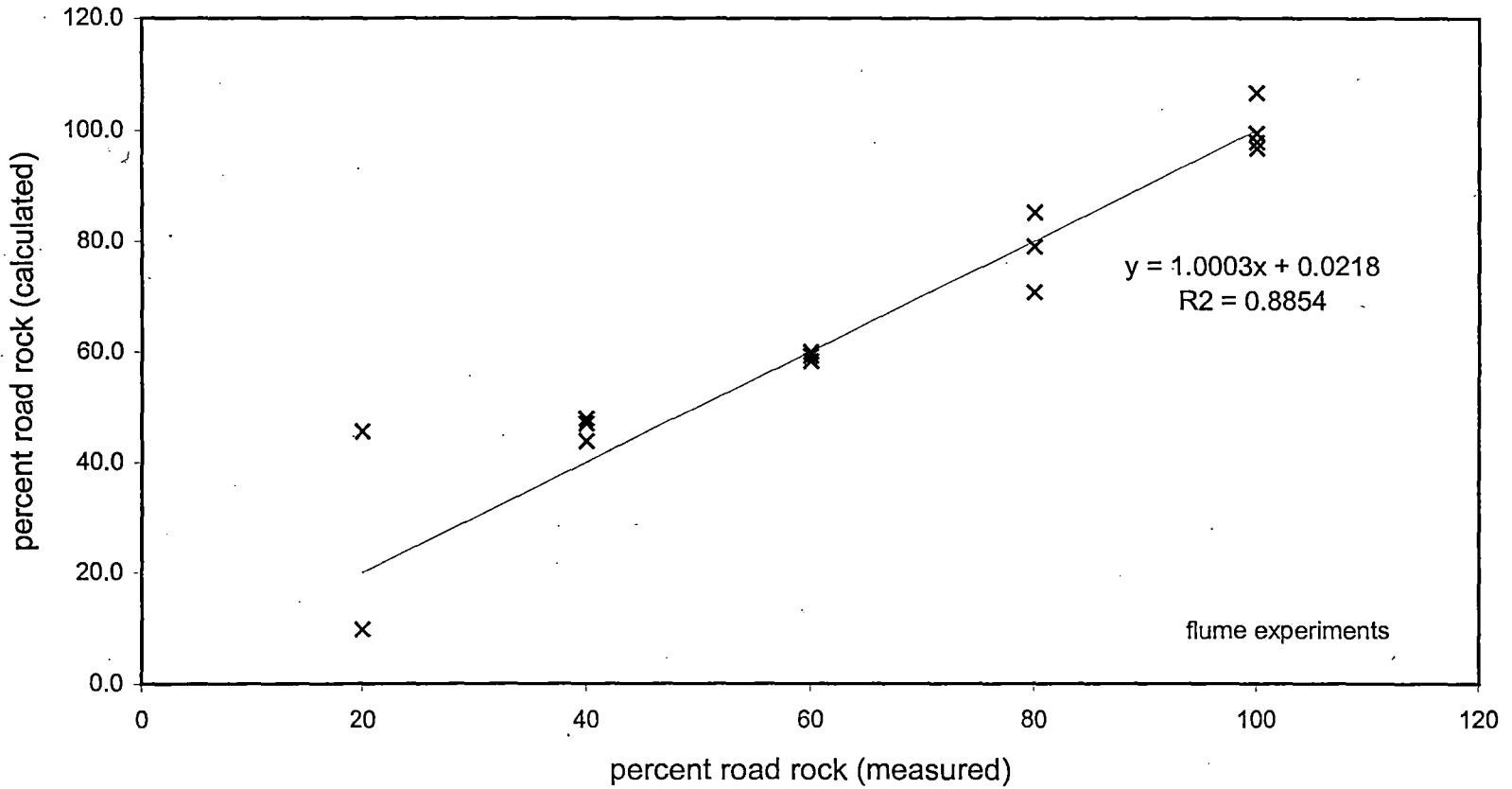


Figure 5: Known percent road rock versus the amount of road rock dertermined from the relationship between peak areas for the flume experiment compositions.

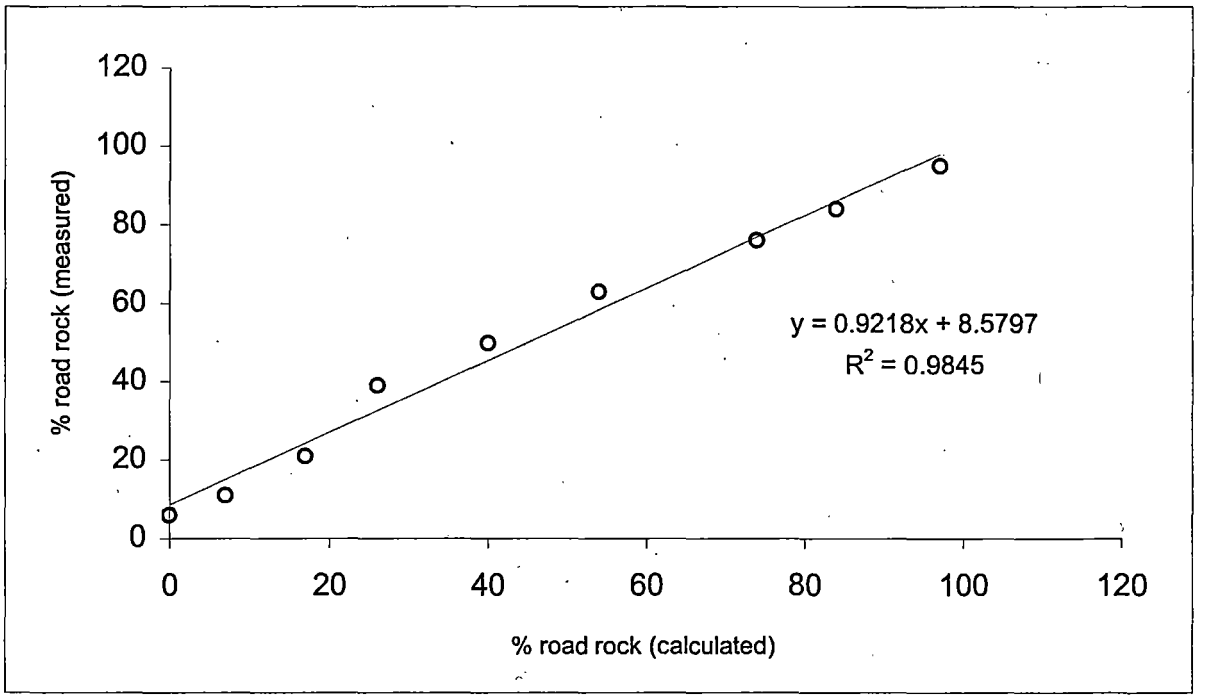
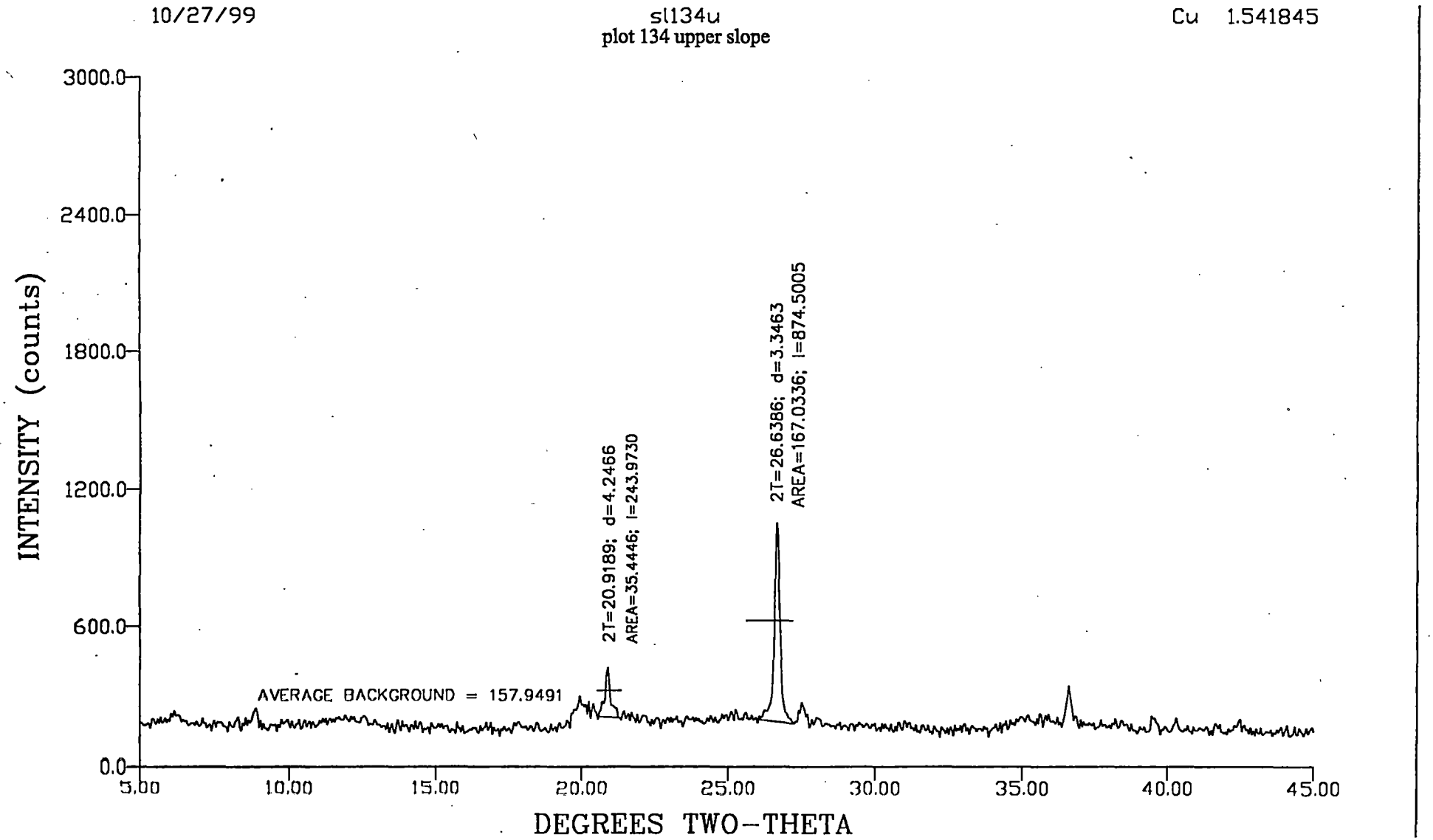
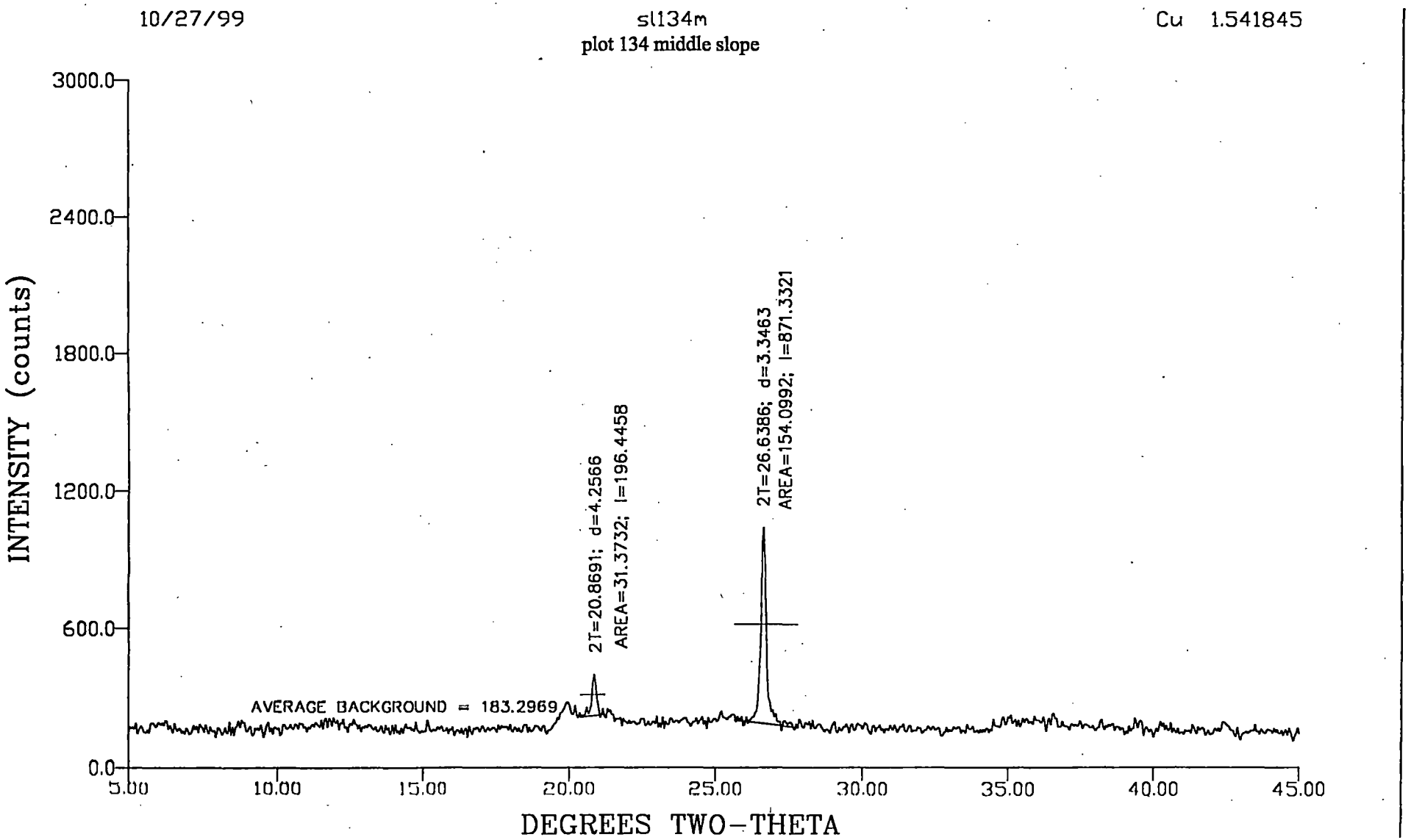


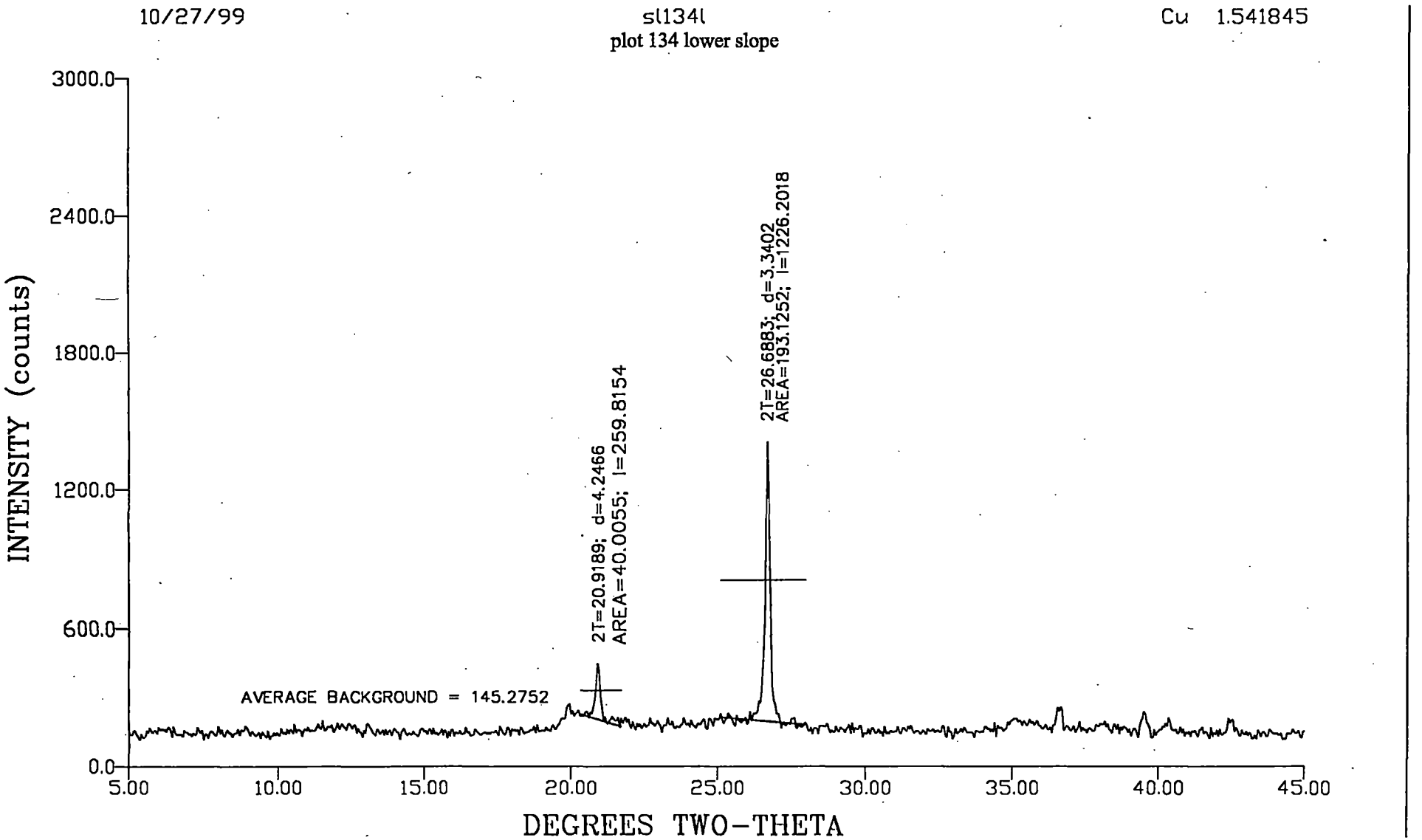
Figure 6: Relationship between measured and calculated densities for known endmember mixtures.

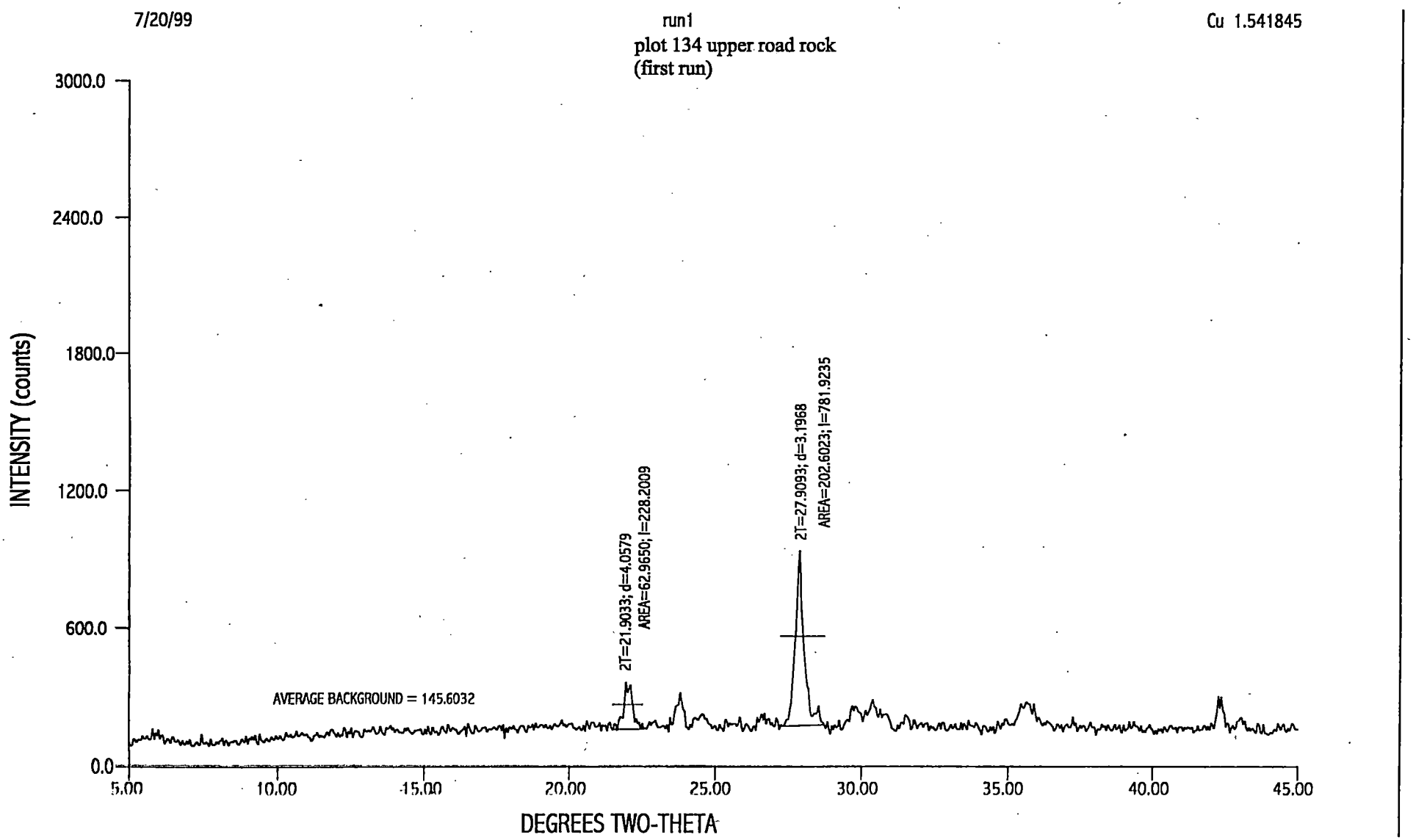
APPENDIX A:

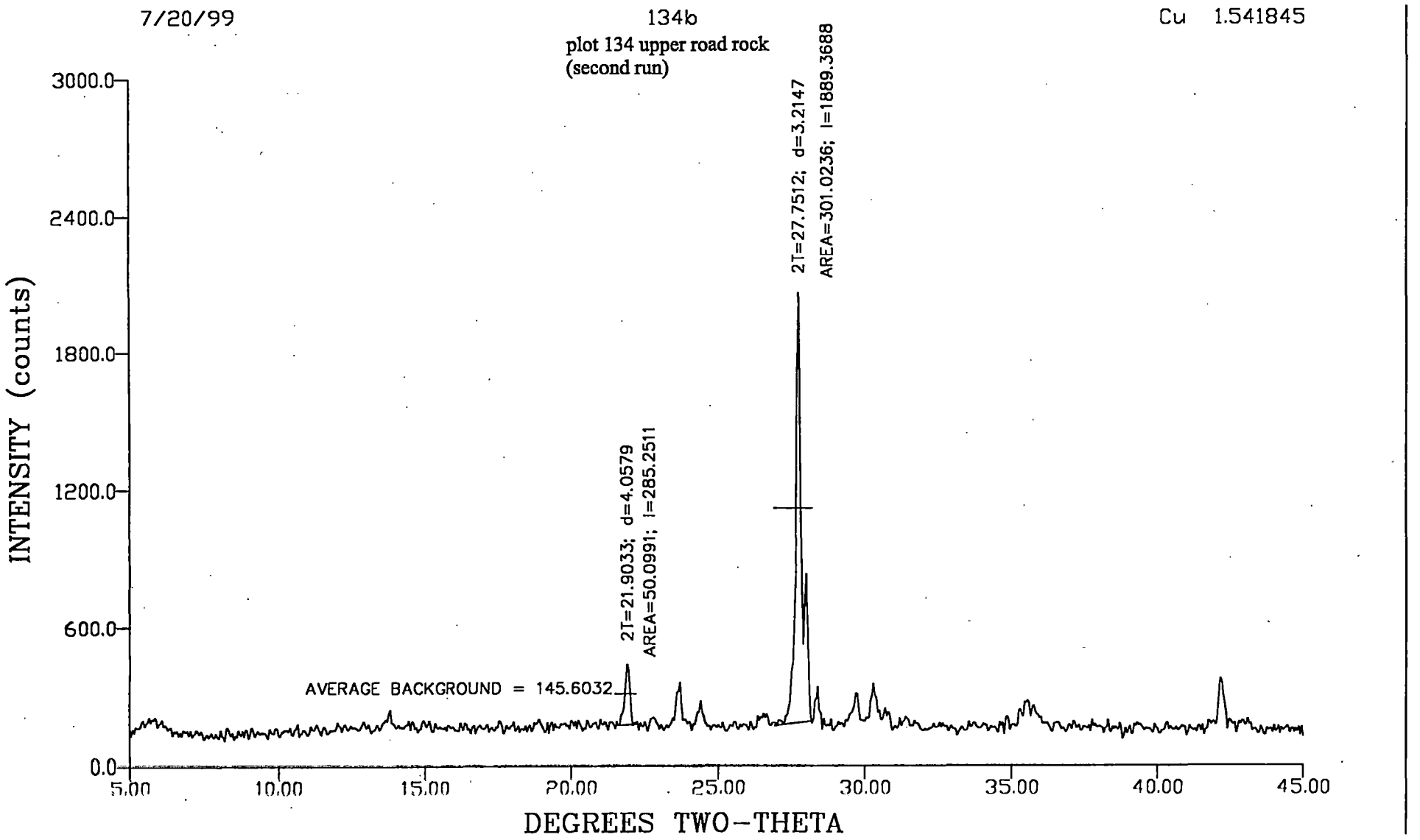
X-ray Diffraction Patterns for Endmember Samples

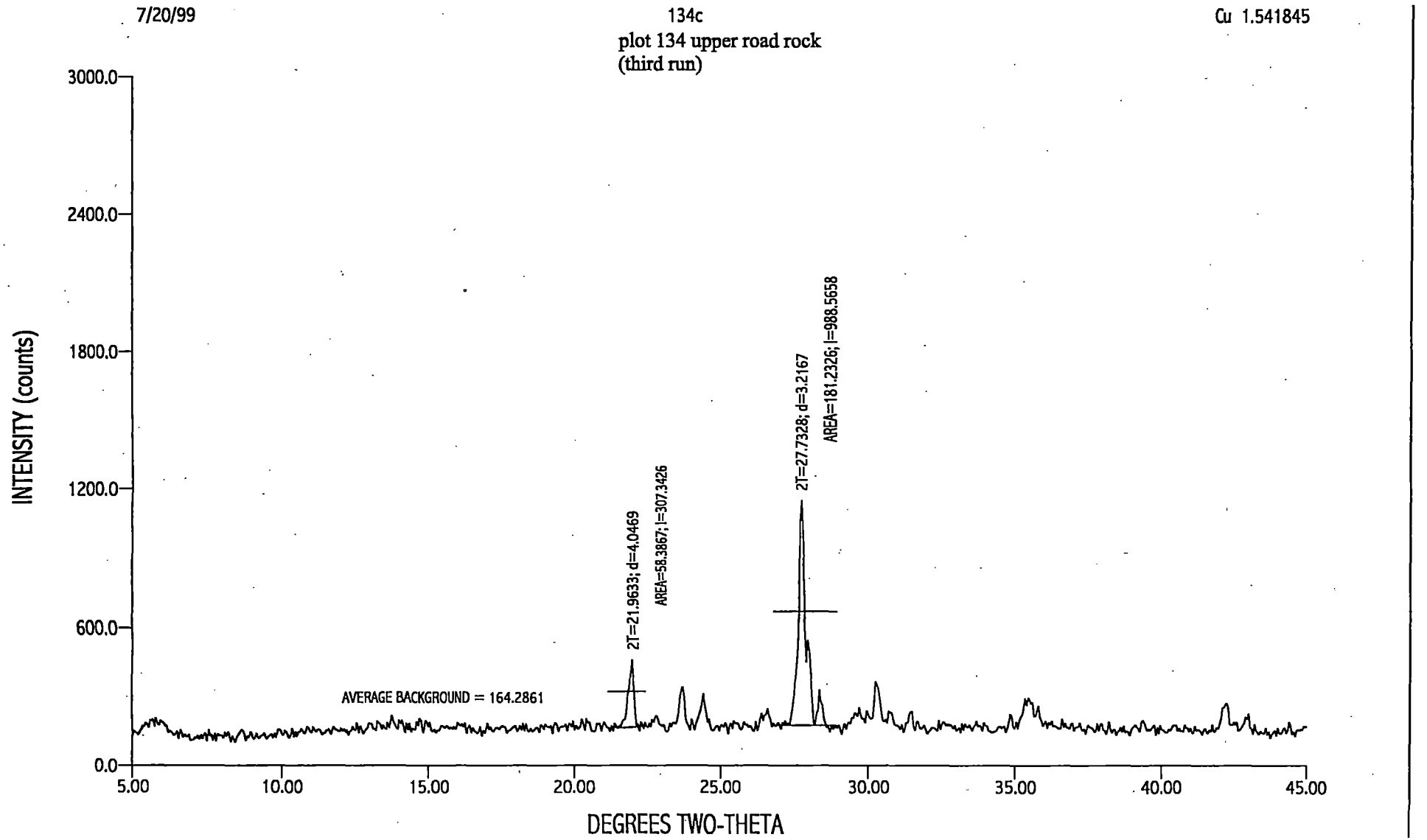

10/27/99
sl134u
plot 134 upper slope
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.9189; d=4.2466
AREA=35.4446; I=243.9730
2T=26.6386; d=3.3463
AREA=167.0336; I=874.5005
AVERAGE BACKGROUND = 157.9491
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
DEGREES TWO-THETA

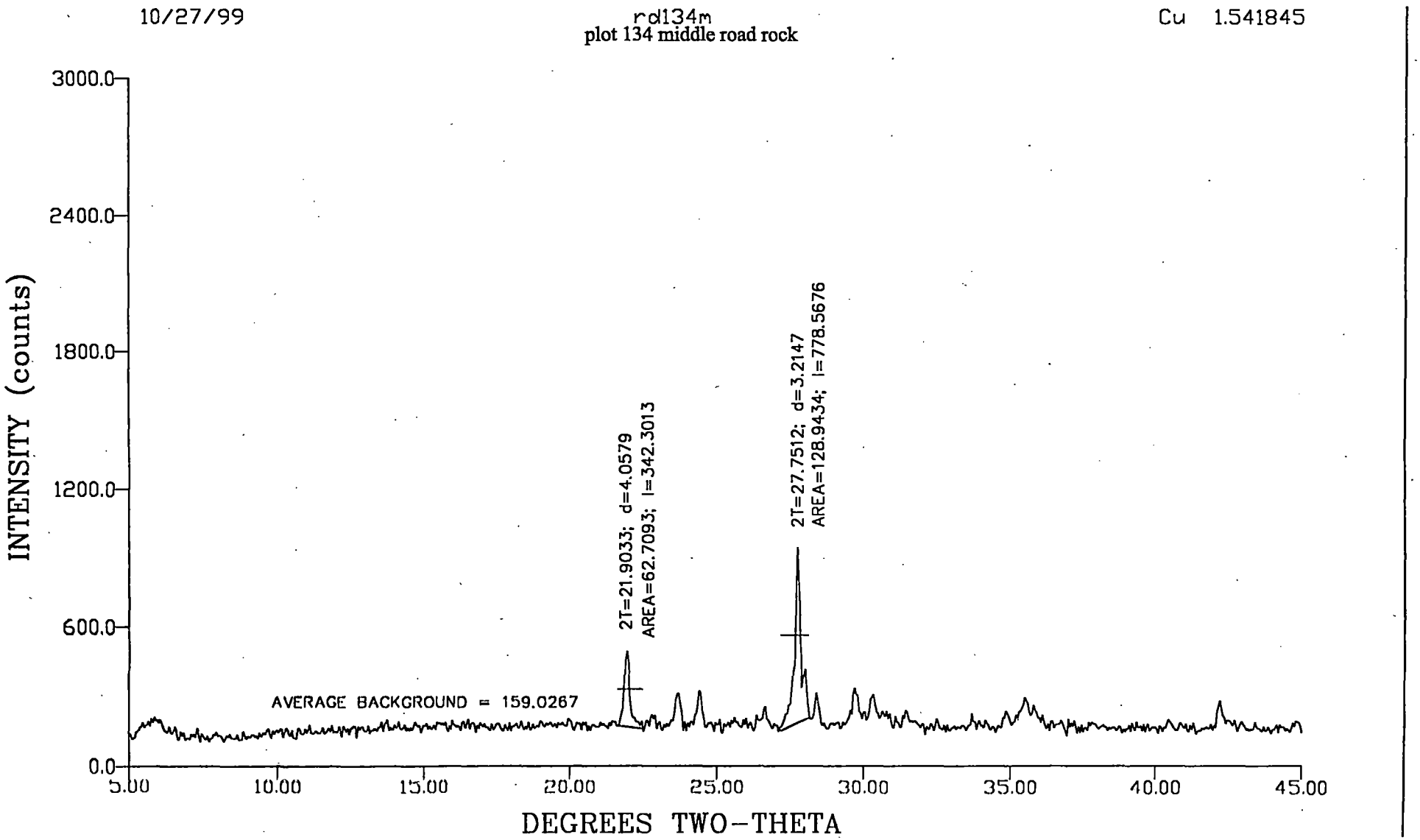

10/27/99
sl134m
plot 134 middle slope
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8691; d=4.2566
AREA=31.3732; I=196.4458
2T=26.6386; d=3.3463
AREA=154.0992; I=871.3321
AVERAGE BACKGROUND = 183.2969
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
DEGREES TWO-THETA

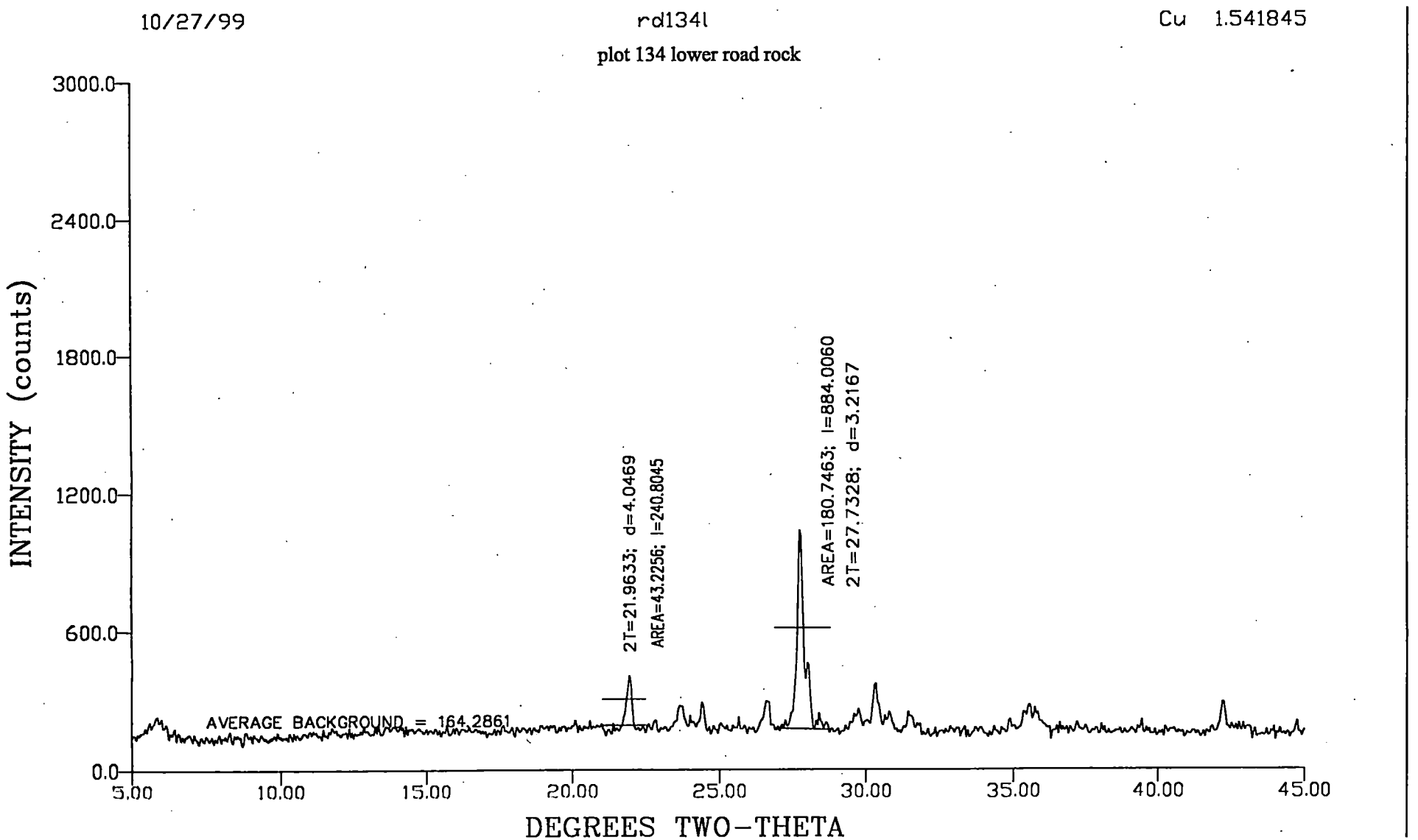

10/27/99
sl134l
plot 134 lower slope
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.9189; d=4.2466
AREA=40.0055; I=259.8154
2T=26.6883; d=3.3402
AREA=193.1252; I=1226.2018
AVERAGE BACKGROUND = 145.2752
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
DEGREES TWO-THETA


7/20/99
run1
Cu 1.541845
plot 134 upper road rock
(first run)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=21.9033; d=4.0579
AREA=62.9650; I=228.2009
2T=27.9093; d=3.1968
AREA=202.6023; I=781.9235
AVERAGE BACKGROUND = 145.6032
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
DEGREES TWO-THETA


7/20/99
134b
Cu 1.541845
plot 134 upper road rock
(second run)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=27.7512; d=3.2147
AREA=301.0236; I=1889.3688
2T=21.9033; d=4.0579
AREA=50.0991; I=285.2511
AVERAGE BACKGROUND = 145.6032
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
DEGREES TWO-THETA

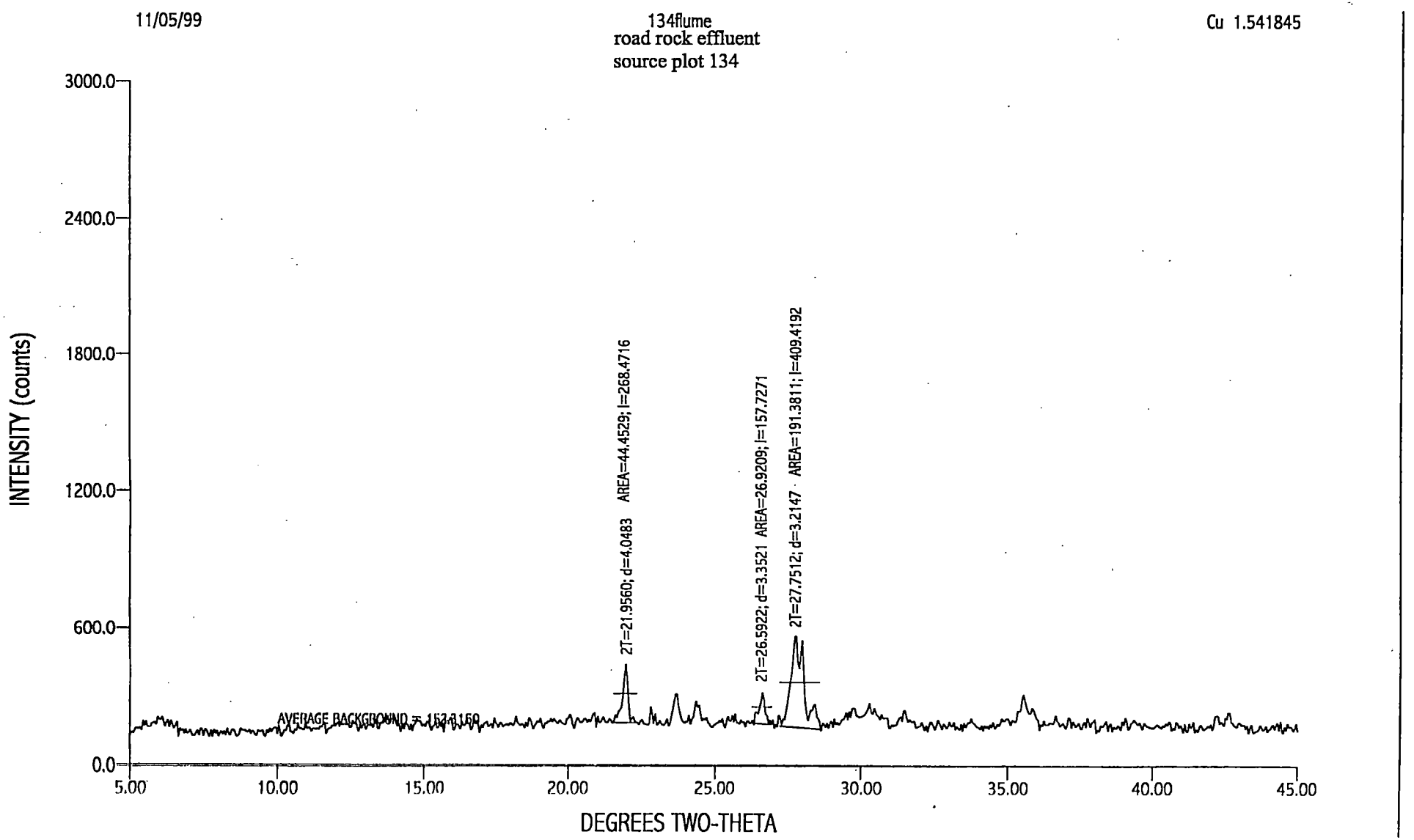

7/20/99
134c
Cu 1.541845
plot 134 upper road rock
(third run)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=21.9633; d=4.0469
AREA=58.3867; I=307.3426
2T=27.7328; d=3.2167
AREA=181.2326; I=988.5658
AVERAGE BACKGROUND = 164.2861
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
DEGREES TWO-THETA

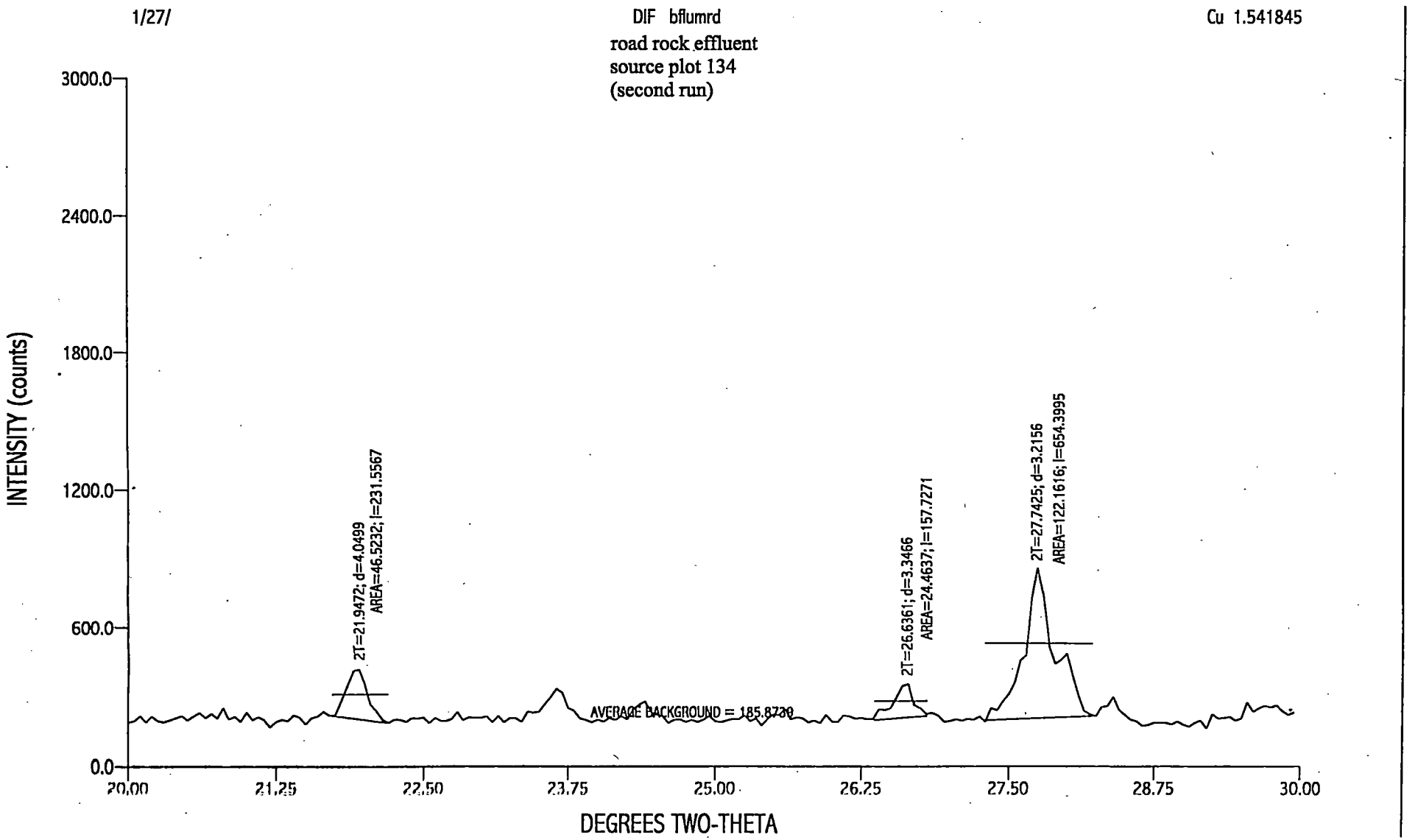

10/27/99
rd134m
plot 134 middle road rock
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=21.9033; d=4.0579
AREA=62.7093; I=342.3013
2T=27.7512; d=3.2147
AREA=128.9434; I=778.5676
AVERAGE BACKGROUND = 159.0267
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
DEGREES TWO-THETA


10/27/99
rd134l
Cu 1.541845
plot 134 lower road rock
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=21.9633; d=4.0469
AREA=43.2256; I=240.8045
AREA=180.7463; I=884.0060
2T=27.7328; d=3.2167
AVERAGE BACKGROUND = 164.2861
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
DEGREES TWO-THETA

APPENDIX B:

X-ray Diffraction Patterns for Flume Experiment Samples


11/05/99
134flume
road rock effluent
source plot 134
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=21.9560; d=4.0483 AREA=44.4529; I=268.4716
2T=26.5922; d=3.3521 AREA=26.9209; I=157.7271
2T=27.7512; d=3.2147 AREA=191.3811; I=409.4192
AVERAGE BACKGROUND = 153.8160
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
DEGREES TWO-THETA

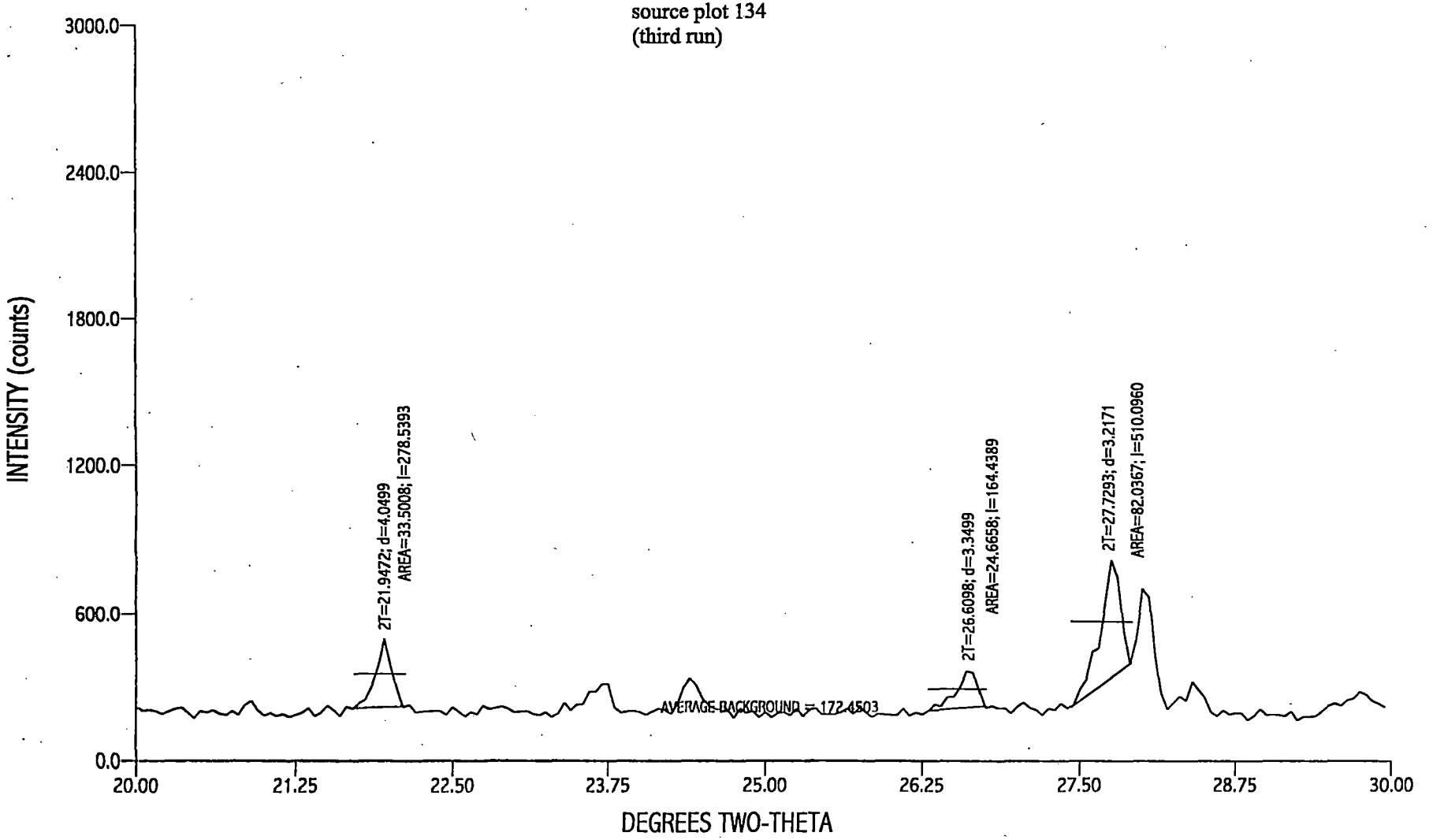

1/27/
DIF bflumrd
road rock effluent
source plot 134
(second run)
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=21.9472; d=4.0499
AREA=46.5232; I=231.5567
2T=26.6361; d=3.3466
AREA=24.4637; I=157.7271
2T=27.7425; d=3.2156
AREA=122.1616; I=654.3995
AVERAGE BACKGROUND = 185.8730
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THETA

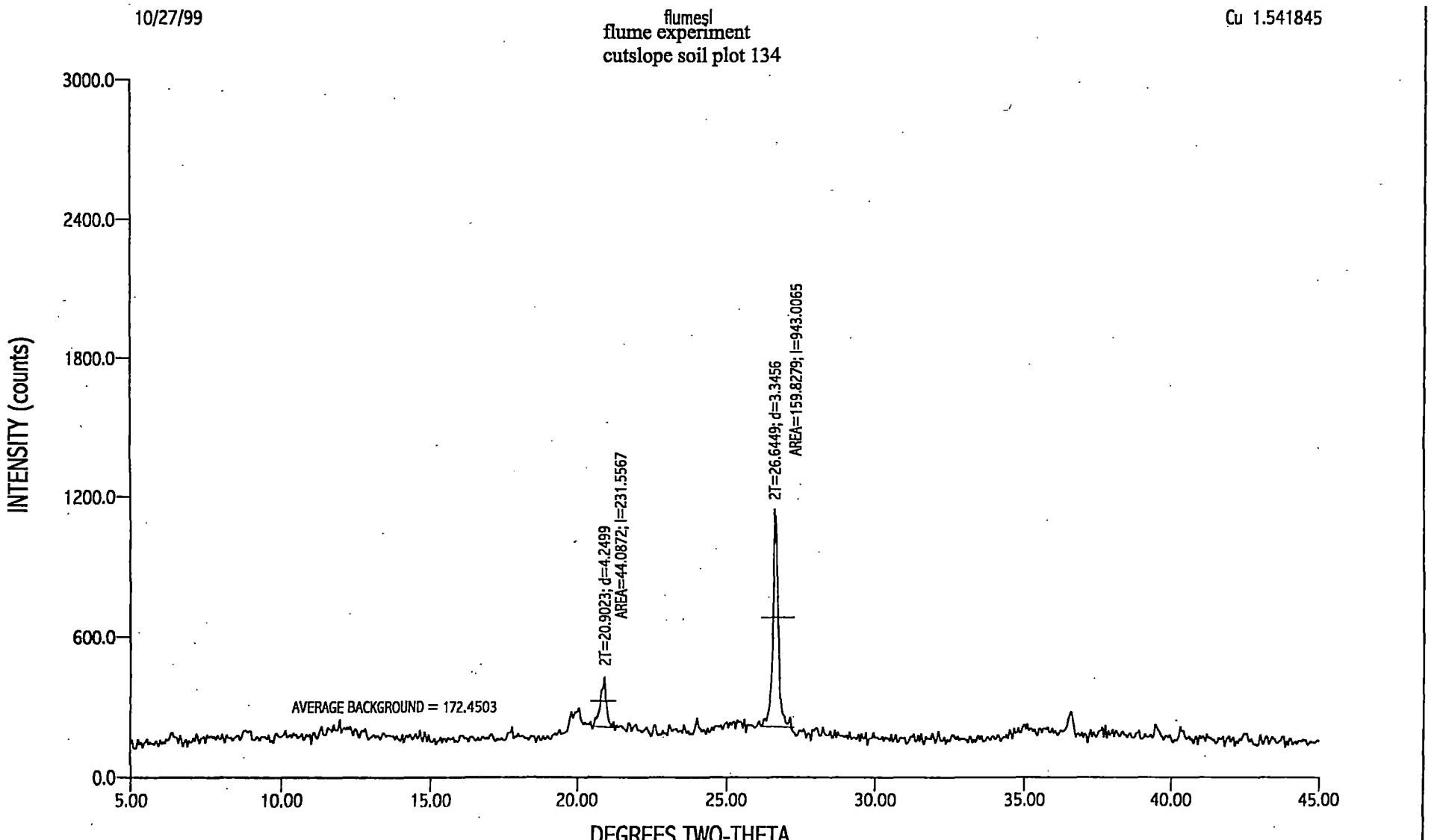
1/27/

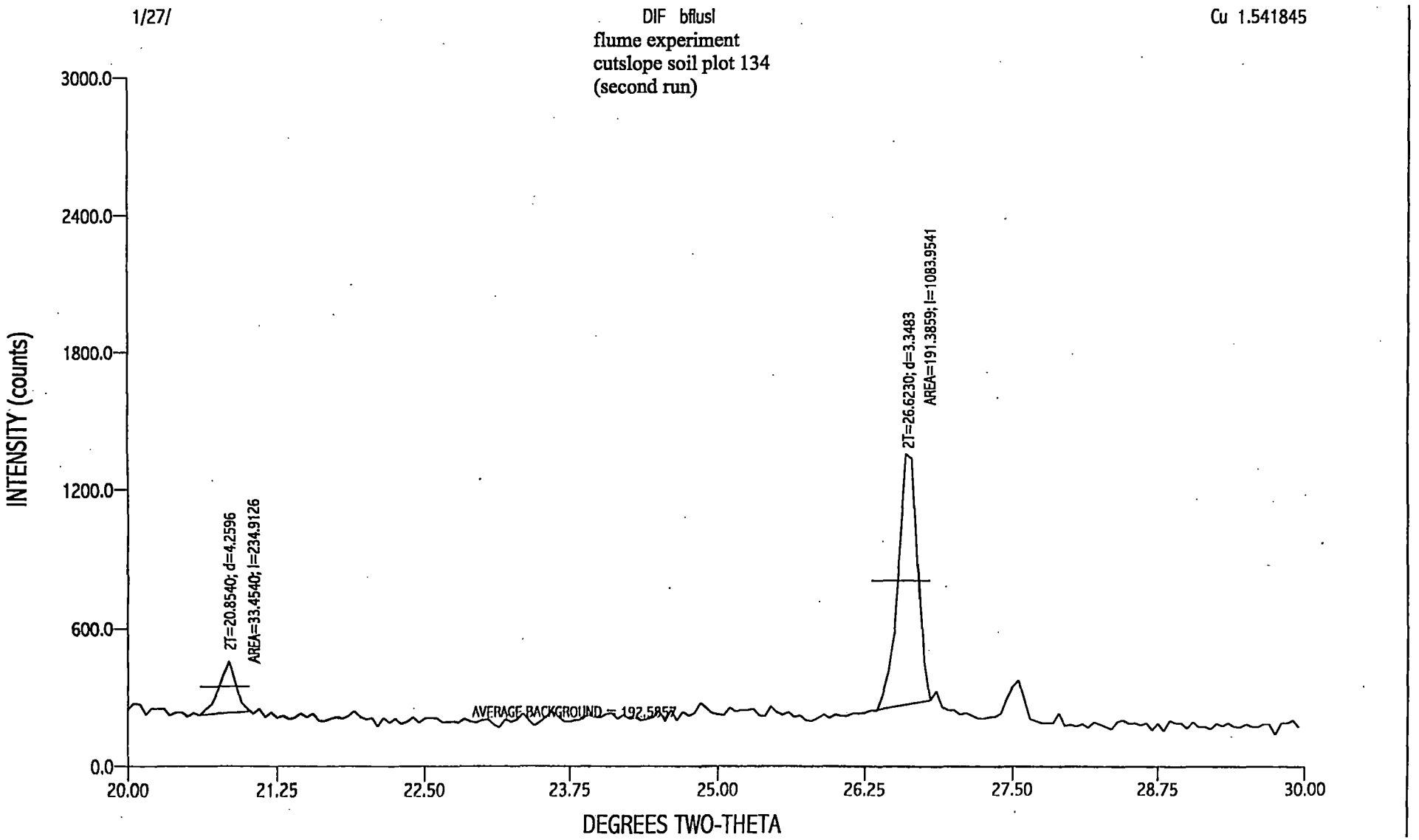
DIF cflumrd

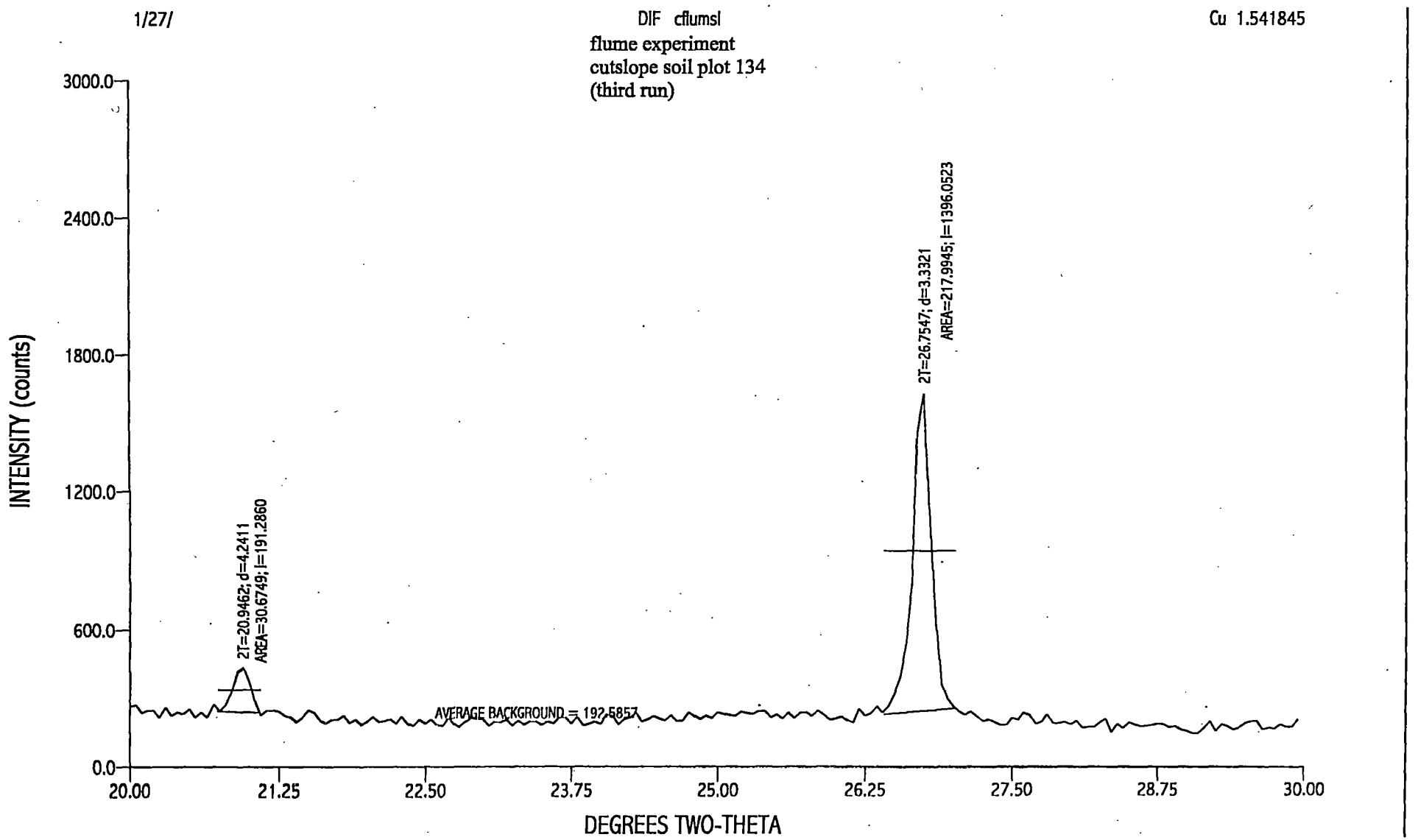
road rock effluent
source plot 134
(third run)

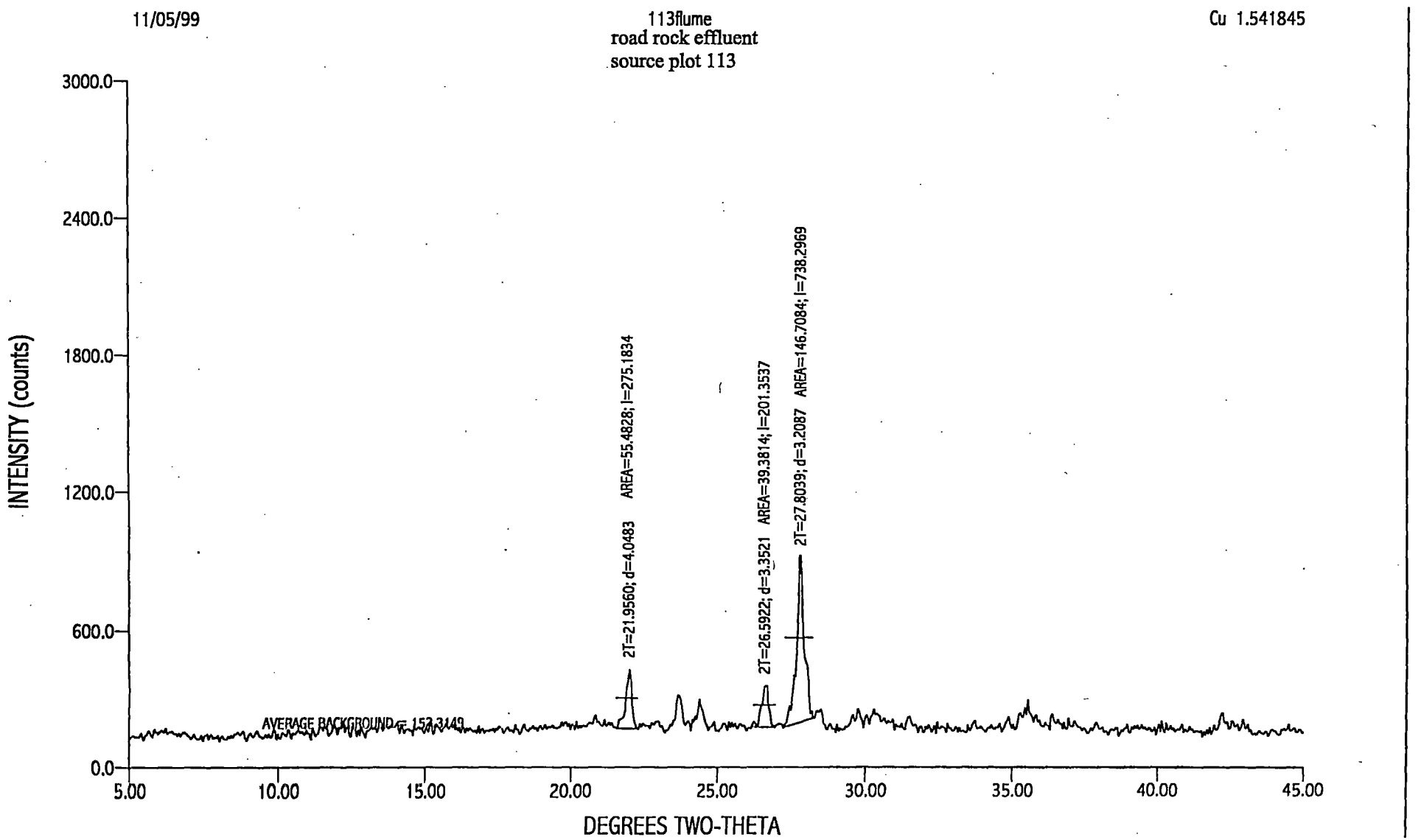
Cu 1.541845




10/27/99
flumes|
flume experiment
cutslope soil plot 134
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.9023; d=4.2499
AREA=44.0872; I=231.5567
2T=26.6449; d=3.3456
AREA=159.8279; I=943.0065
AVERAGE BACKGROUND = 172.4503
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
DEGREES TWO-THETA

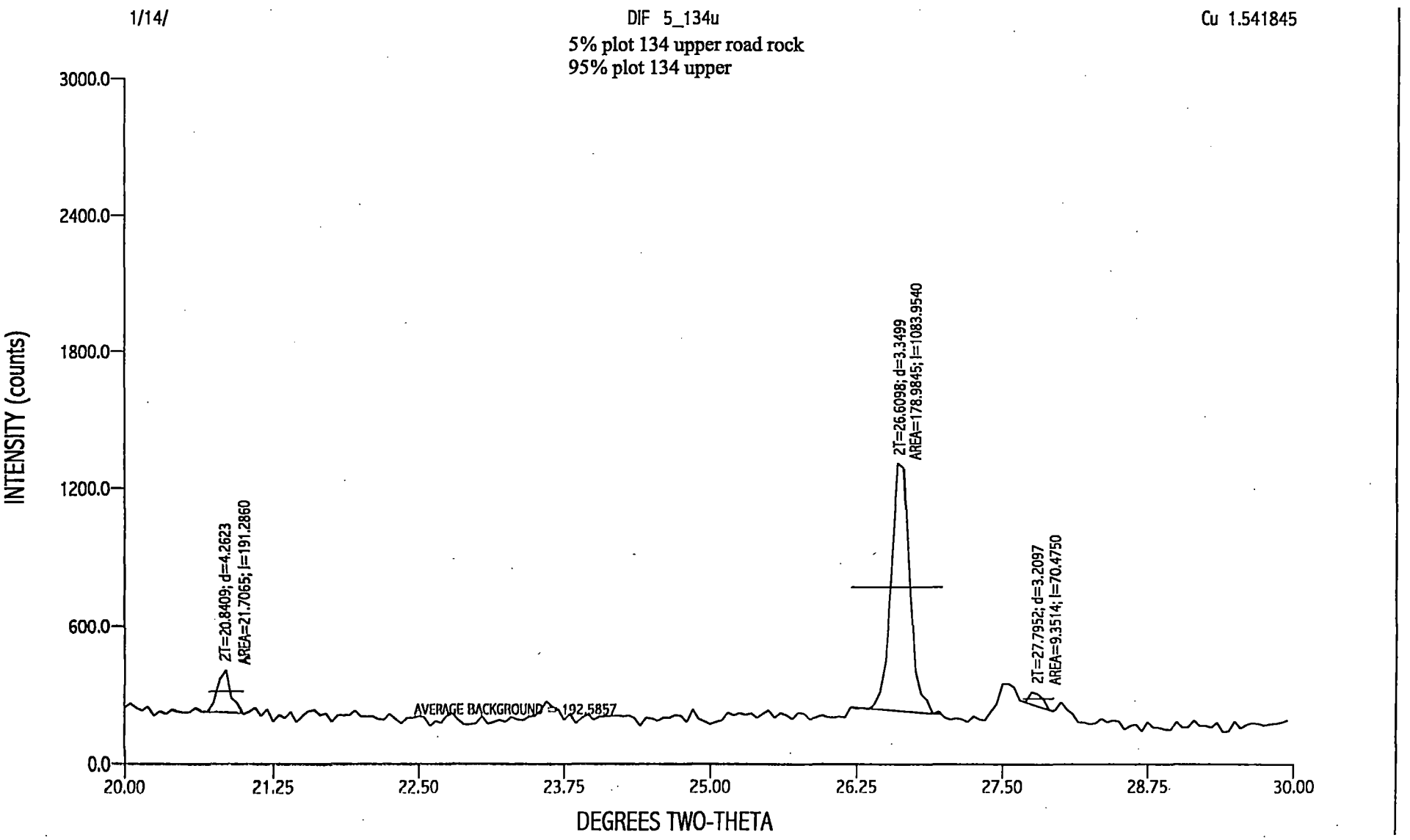

1/27/
DIF bflusl
flume experiment
cutslope soil plot 134
(second run)
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8540; d=4.2596
AREA=33.4540; I=234.9126
2T=26.6230; d=3.3483
AREA=191.3859; I=1083.9541
AVERAGE BACKGROUND = 192.5857
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THETA


1/27/
DIF cflumsl
Cu 1.541845
flume experiment
cutslope soil plot 134
(third run)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.9462; d=4.2411
AREA=30.6749; I=191.2860
2T=26.7547; d=3.3321
AREA=217.9945; I=1396.0523
AVERAGE BACKGROUND = 192.5857
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THETA


11/05/99
113flume
road rock effluent
source plot 113
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=21.9560; d=4.0483 AREA=55.4828; I=275.1834
2T=26.5922; d=3.3521 AREA=39.3814; I=201.3537
2T=27.8039; d=3.2087 AREA=146.7084; I=738.2969
AVERAGE BACKGROUND = 152.3149
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
DEGREES TWO-THETA

APPENDIX C:

X-ray Diffraction Patterns for Mixtures of Road Rock and Cutslope Material in Known Proportions

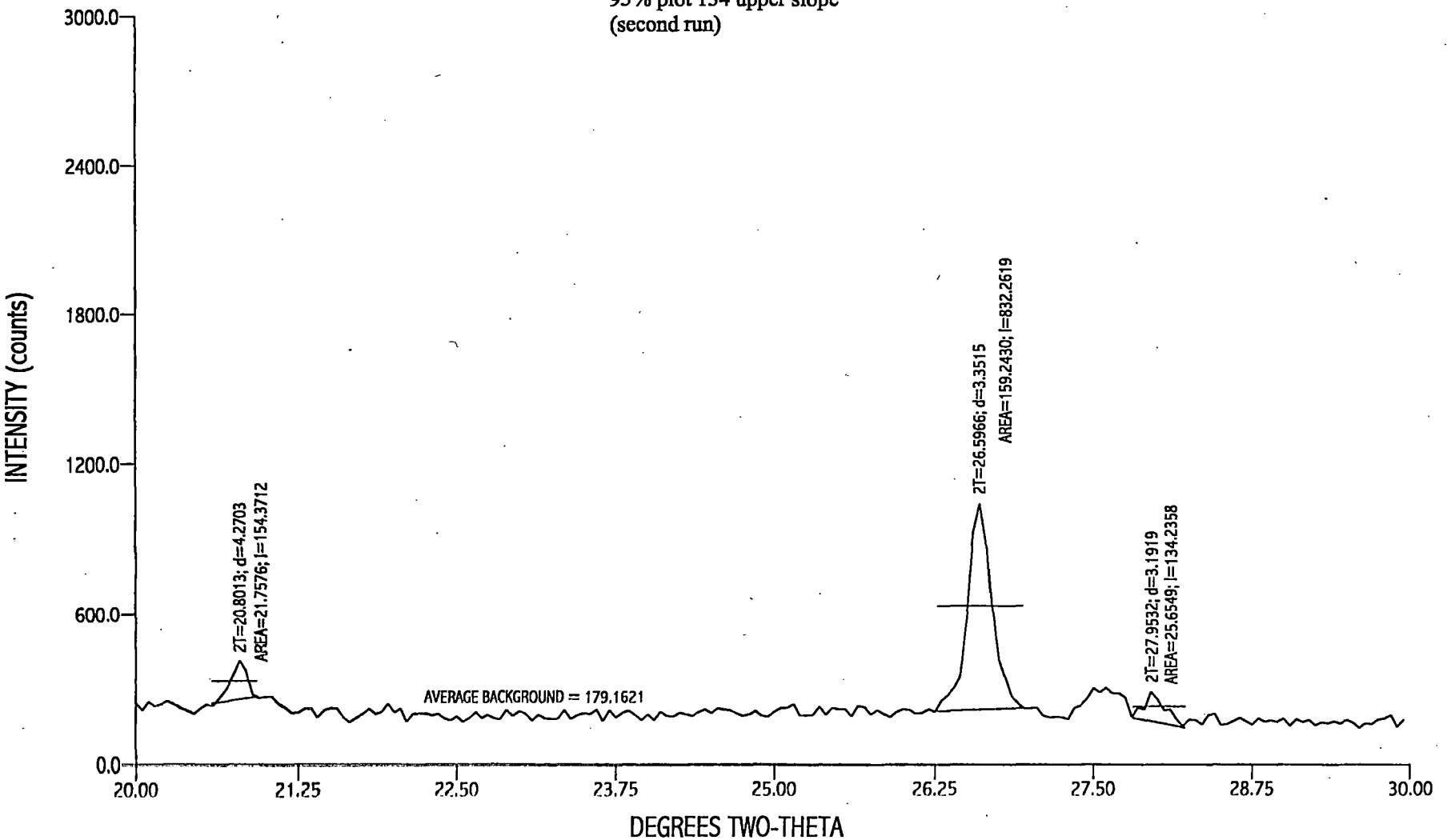

1/14/
DIF 5_134u
Cu 1.541845
5% plot 134 upper road rock
95% plot 134 upper
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8409; d=4.2623
AREA=21.7065; I=191.2860
2T=26.6098; d=3.3499
AREA=178.9845; I=1083.9540
2T=27.7952; d=3.2097
AREA=9.3514; I=70.4750
AVERAGE BACKGROUND = 192.5857
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THETA

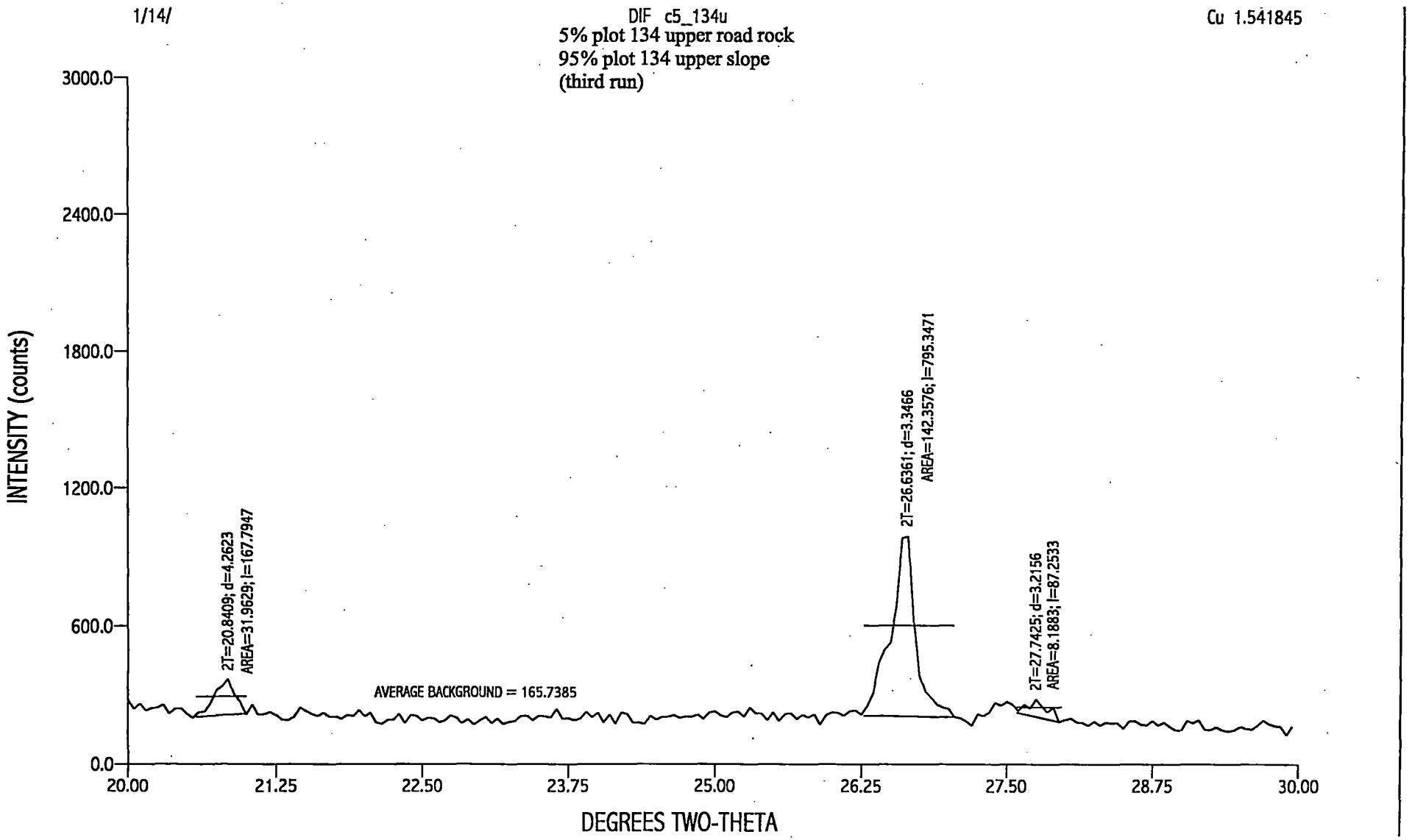
1/14/

DIF b5_134u

Cu 1.541845

5% plot 134 upper road rock
95% plot 134 upper slope
(second run)



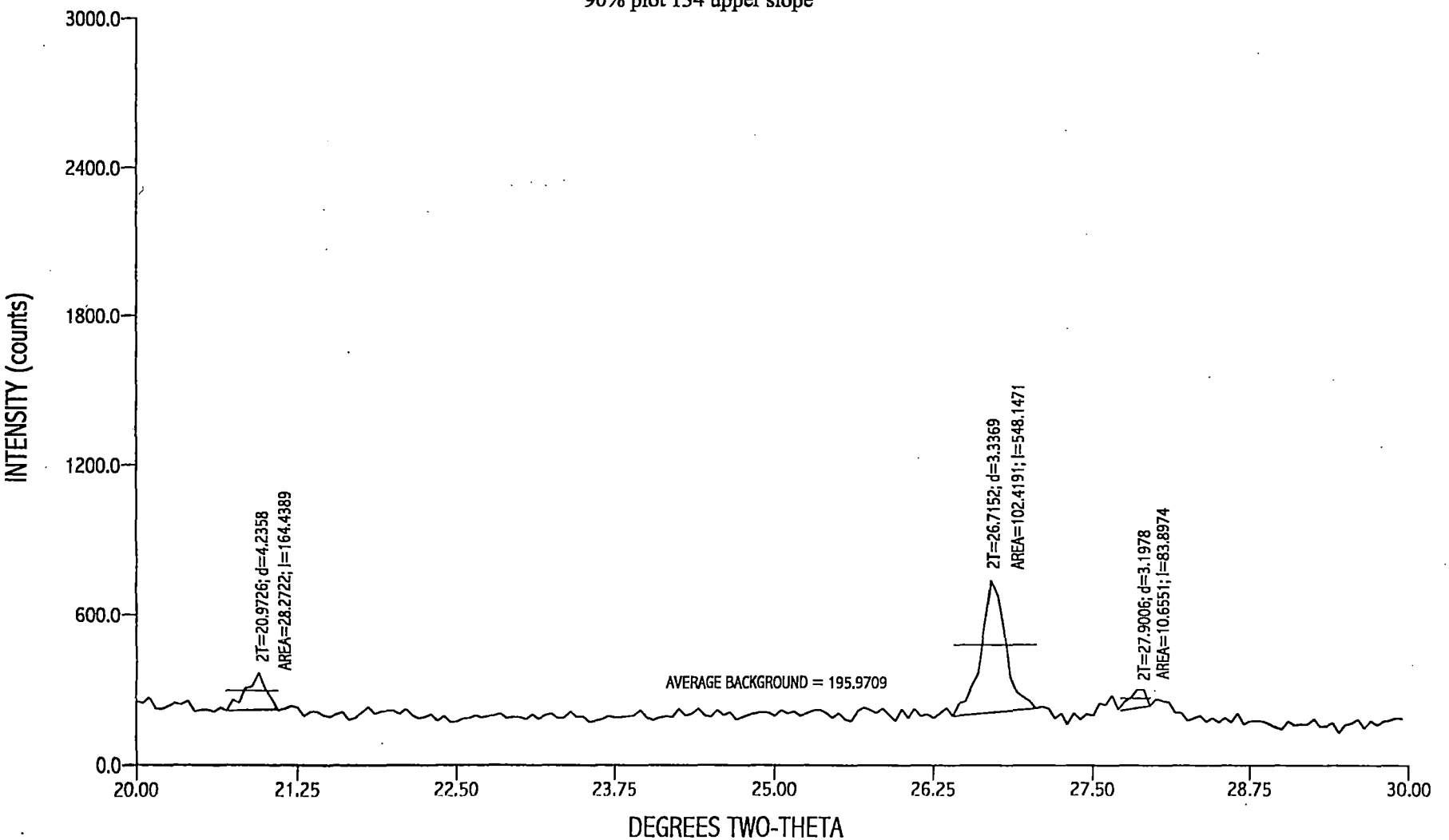

1/14/
DIF c5_134u
5% plot 134 upper road rock
95% plot 134 upper slope
(third run)
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=20.8409; d=4.2623
AREA=31.9629; I=167.7947
AVERAGE BACKGROUND = 165.7385
2T=26.6361; d=3.3466
AREA=142.3576; I=795.3471
2T=27.7425; d=3.2156
AREA=8.1883; I=87.2533
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THETA

1/14/

DIF 10_134u

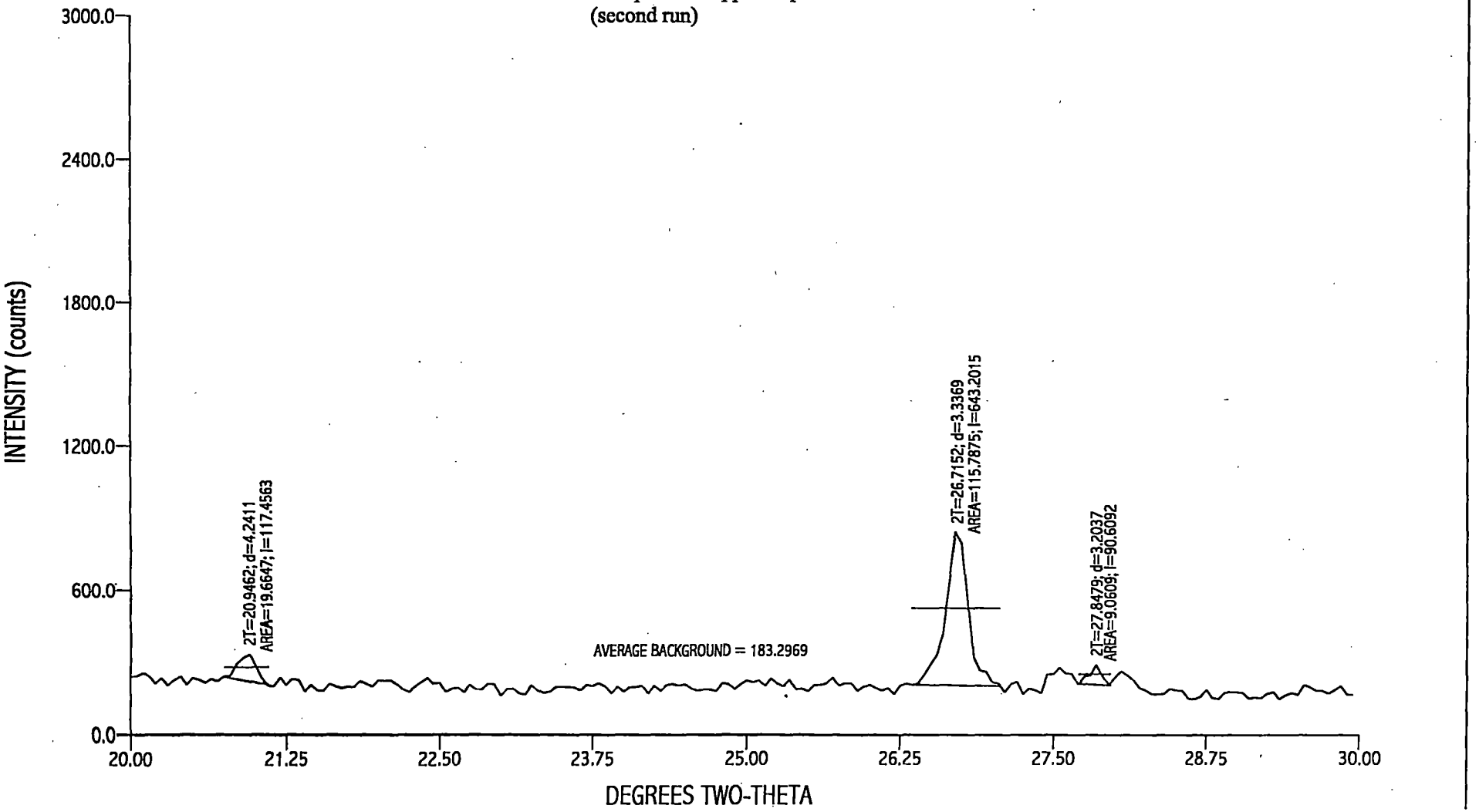
10% plot 134 upper road rock
90% plot 134 upper slope

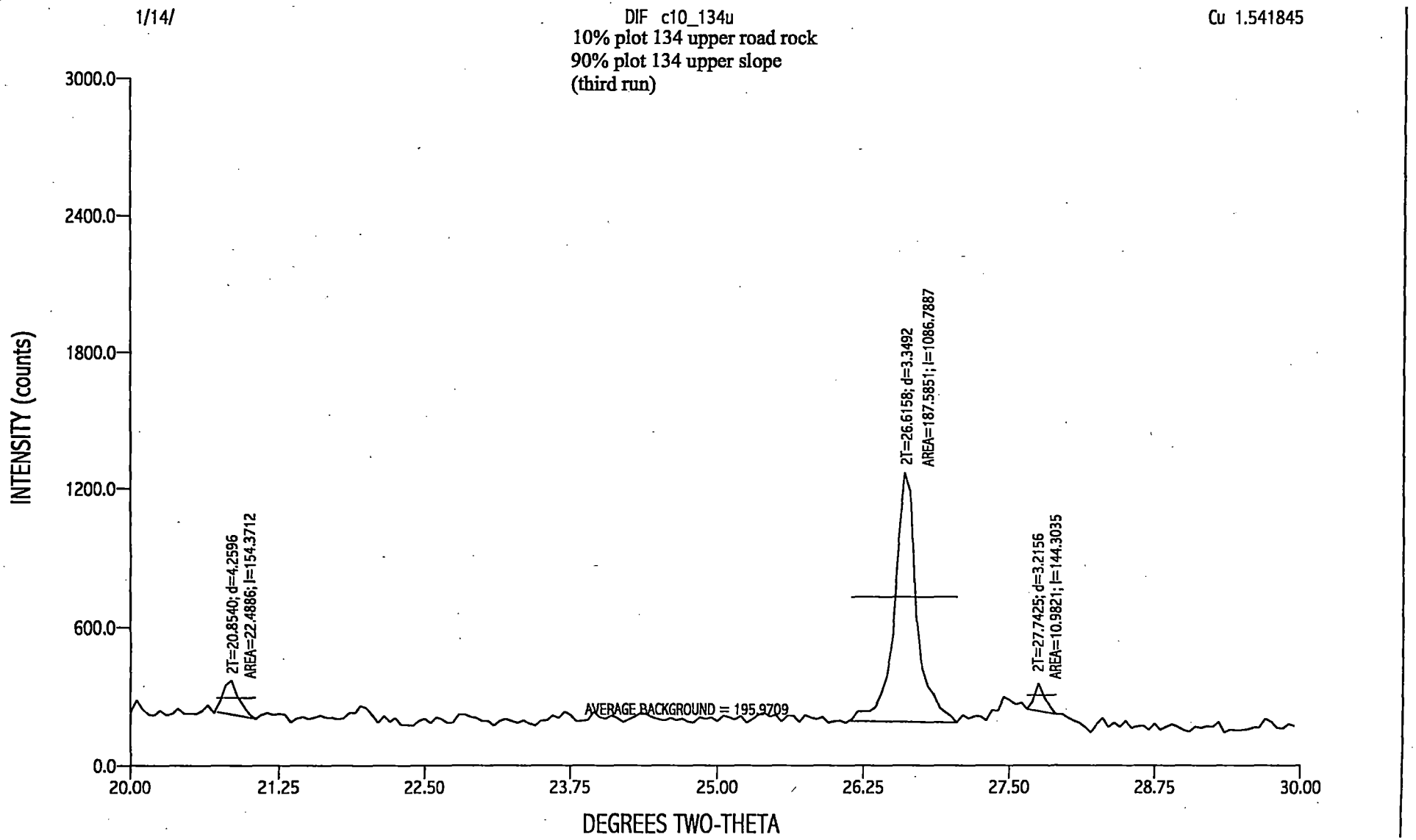
Cu 1.541845



1/14/ DIF b10_134u Cu 1.541845

10% plot 134 upper road rock
90% plot 134 upper slope
(second run)



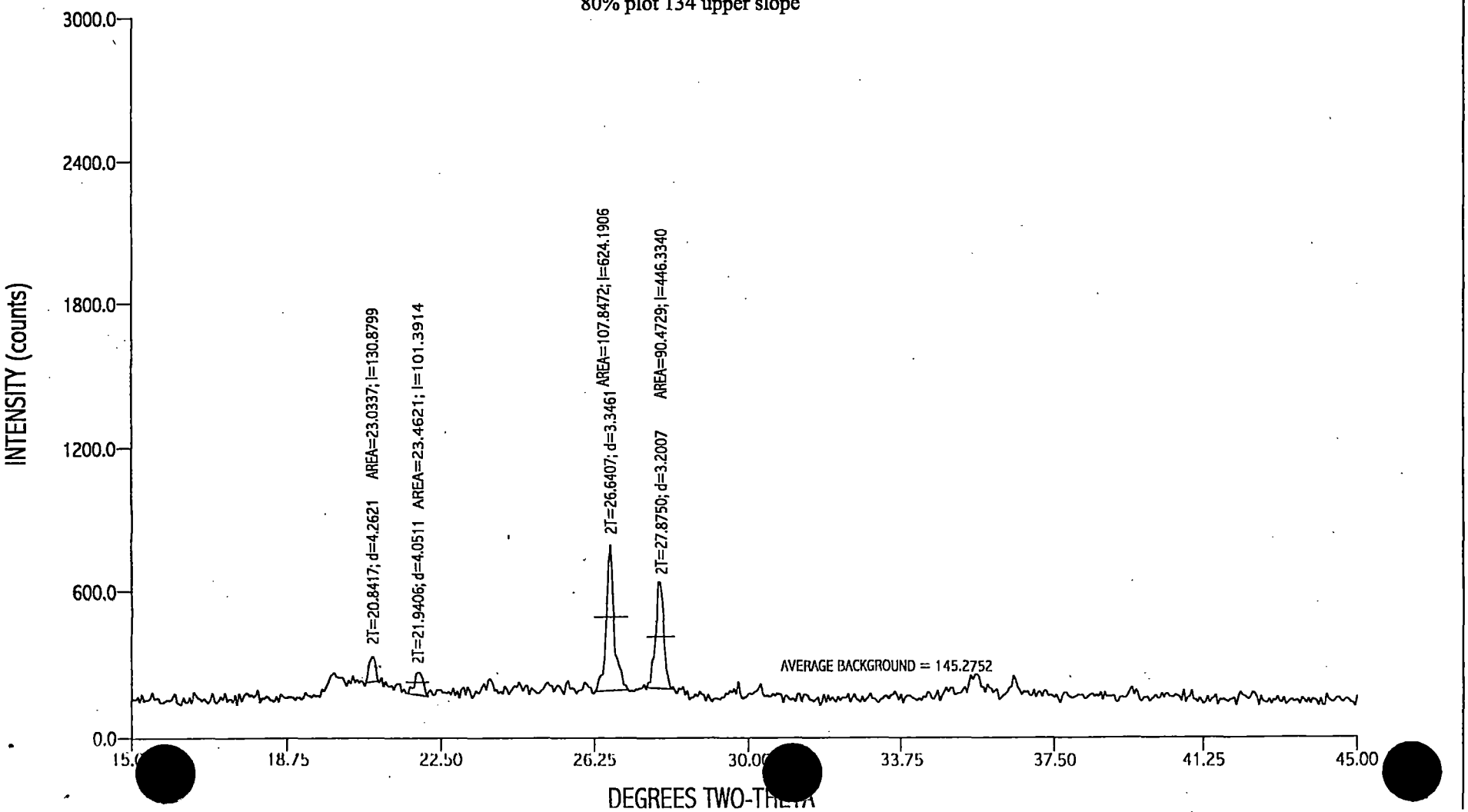

1/14/
DIF c10_134u
10% plot 134 upper road rock
90% plot 134 upper slope
(third run)
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8540; d=4.2596
AREA=22.4886; I=154.3712
2T=26.6158; d=3.3492
AREA=187.5851; I=1086.7887
2T=27.7425; d=3.2156
AREA=10.9821; I=144.3035
AVERAGE BACKGROUND = 195.9709
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THETA

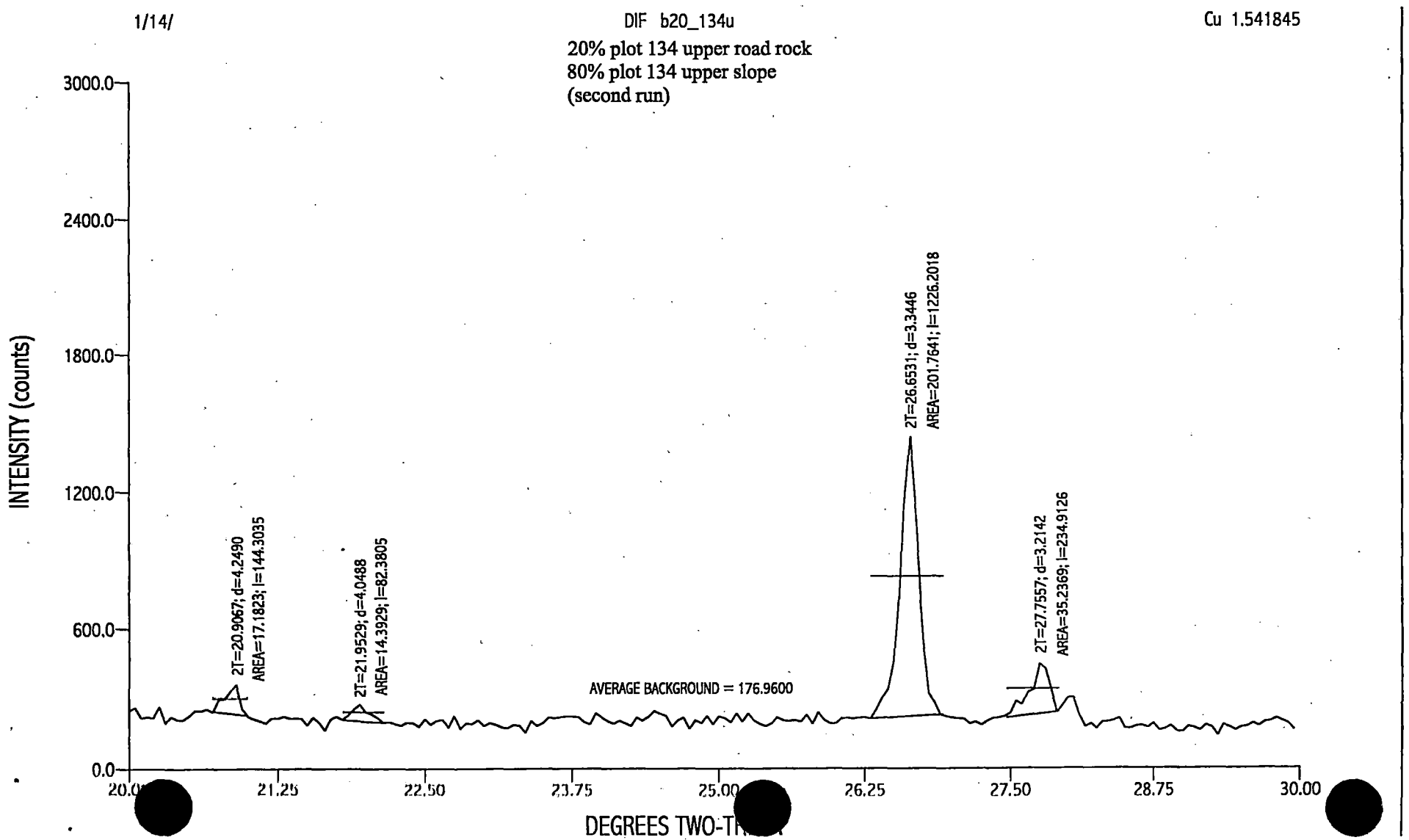
11/04/99

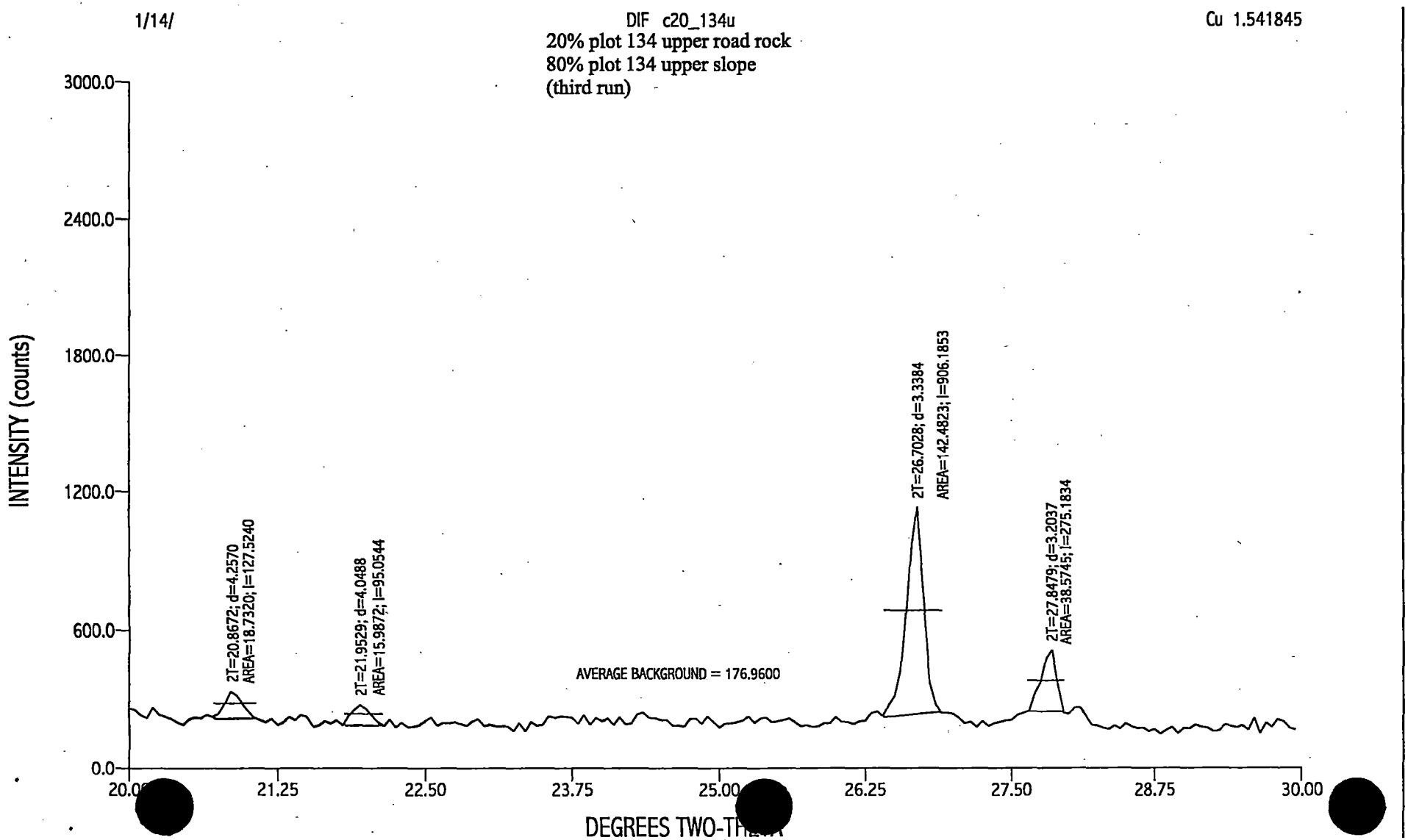
20_134u

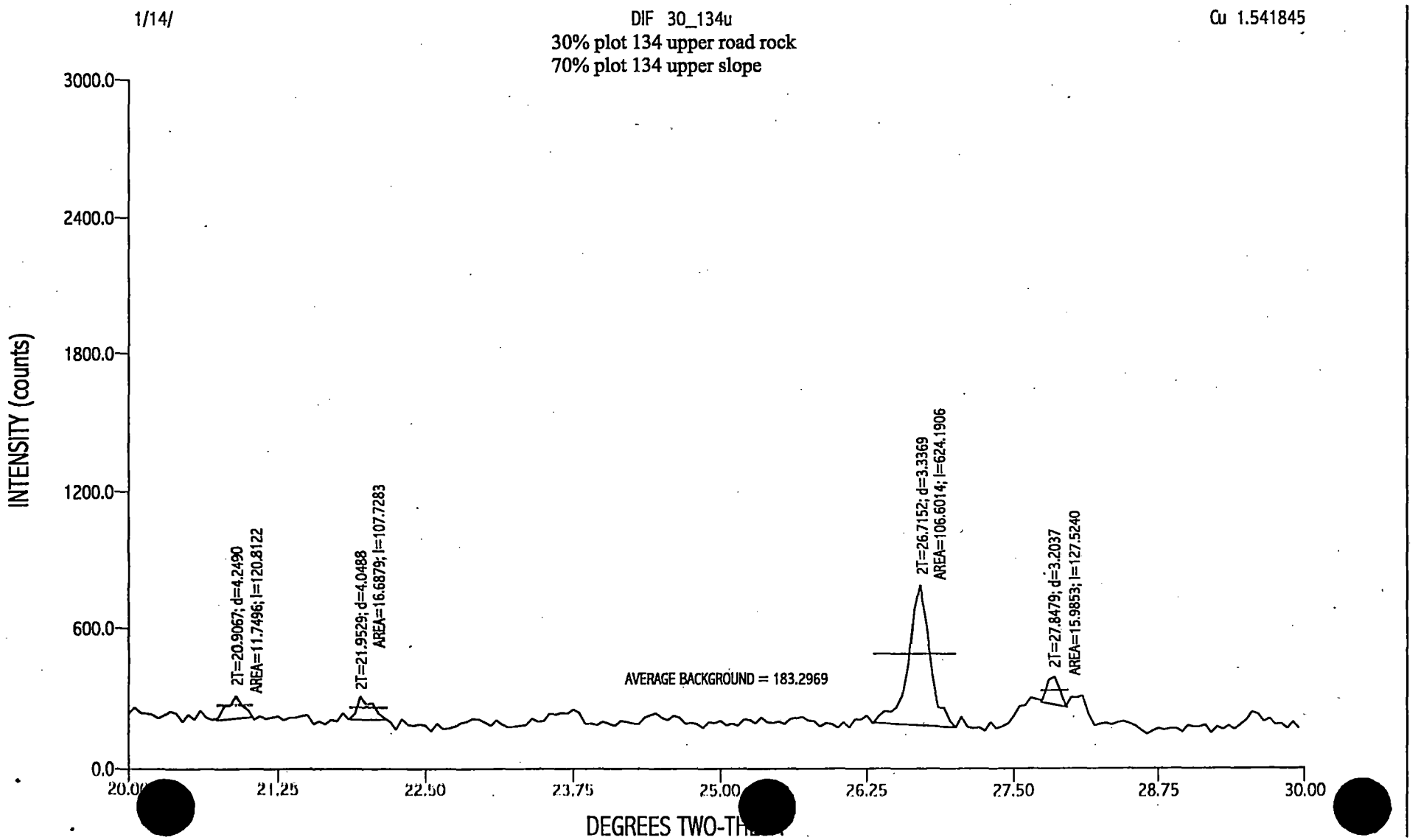
Cu 1.541845

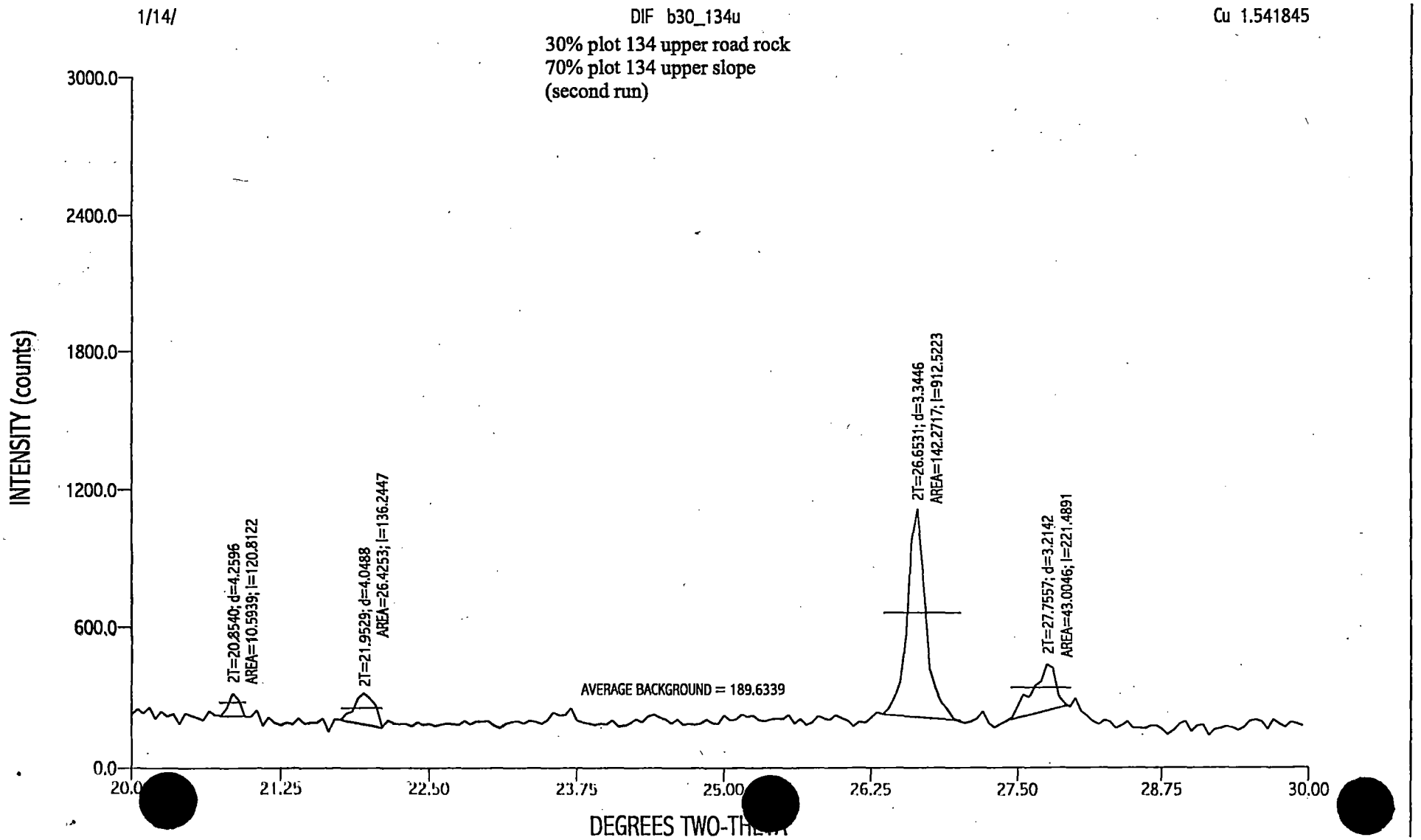
20% plot 134 upper road rock
80% plot 134 upper slope




1/14/
DIF b20_134u
Cu 1.541845
20% plot 134 upper road rock
80% plot 134 upper slope
(second run)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.9067; d=4.2490
AREA=17.1823; I=144.3035
2T=21.9529; d=4.0488
AREA=14.3929; I=82.3805
AVERAGE BACKGROUND = 176.9600
2T=26.6531; d=3.3446
AREA=201.7641; I=1226.2018
2T=27.7557; d=3.2142
AREA=35.2369; I=234.9126
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH


1/14/
DIF c20_134u
20% plot 134 upper road rock
80% plot 134 upper slope
(third run)
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8672; d=4.2570
AREA=18.7320; I=127.5240
2T=21.9529; d=4.0488
AREA=15.9872; I=95.0544
AVERAGE BACKGROUND = 176.9600
2T=26.7028; d=3.3384
AREA=142.4823; I=906.1853
2T=27.8479; d=3.2037
AREA=38.5745; I=275.1834
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH


1/14/
DIF 30_134u
30% plot 134 upper road rock
70% plot 134 upper slope
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=20.9067; d=4.2490
AREA=11.7496; I=120.8122
2T=21.9529; d=4.0488
AREA=16.6879; I=107.7283
AVERAGE BACKGROUND = 183.2969
2T=26.7152; d=3.3369
AREA=106.6014; I=624.1906
2T=27.8479; d=3.2037
AREA=15.9853; I=127.5240
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

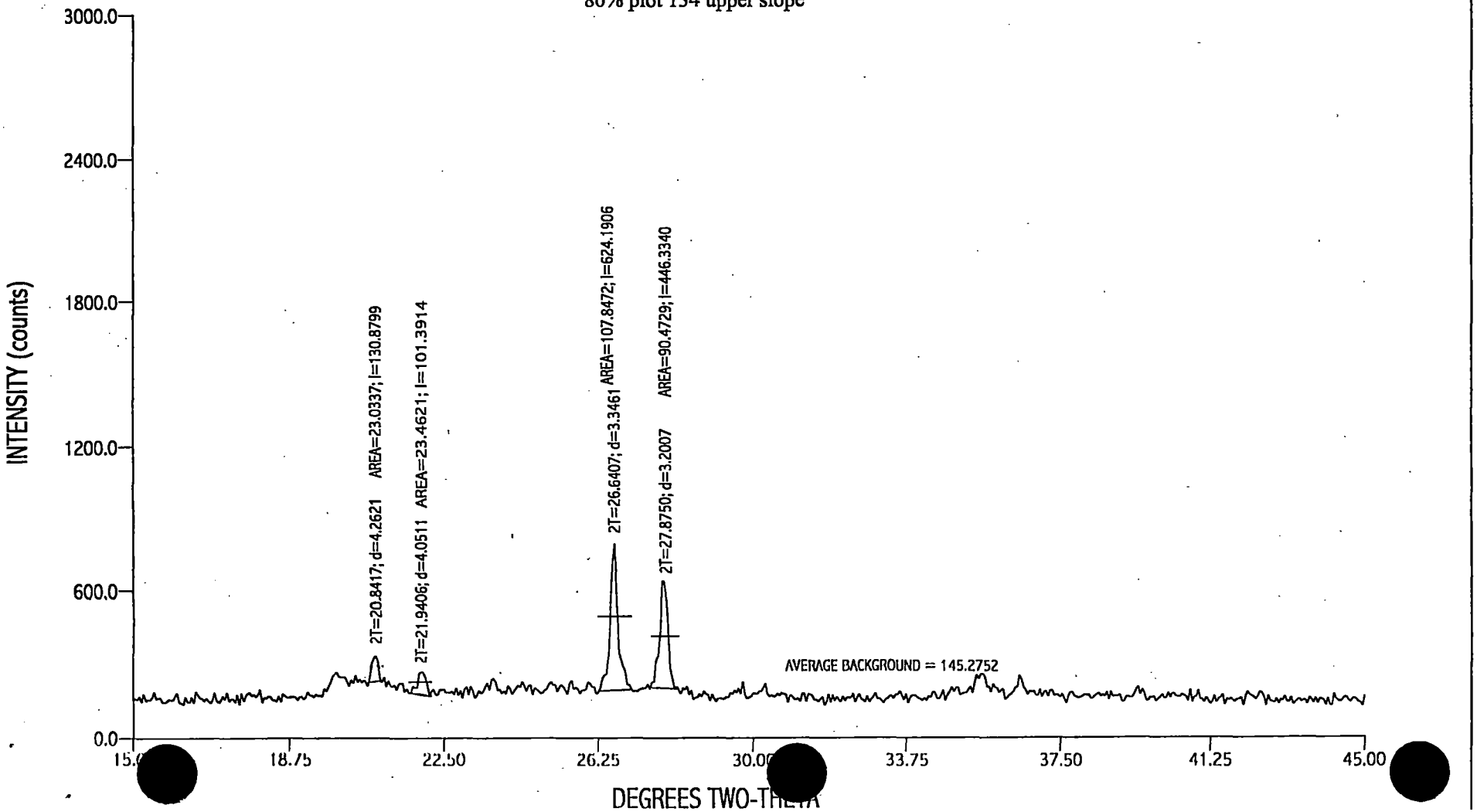

1/14/
DIF b30_134u
Cu 1.541845
30% plot 134 upper road rock
70% plot 134 upper slope
(second run)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8540; d=4.2596
AREA=10.5939; I=120.8122
2T=21.9529; d=4.0488
AREA=26.4253; I=136.2447
AVERAGE BACKGROUND = 189.6339
2T=26.6531; d=3.3446
AREA=142.2717; I=912.5223
2T=27.7557; d=3.2142
AREA=43.0046; I=221.4891
20.0
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THETA

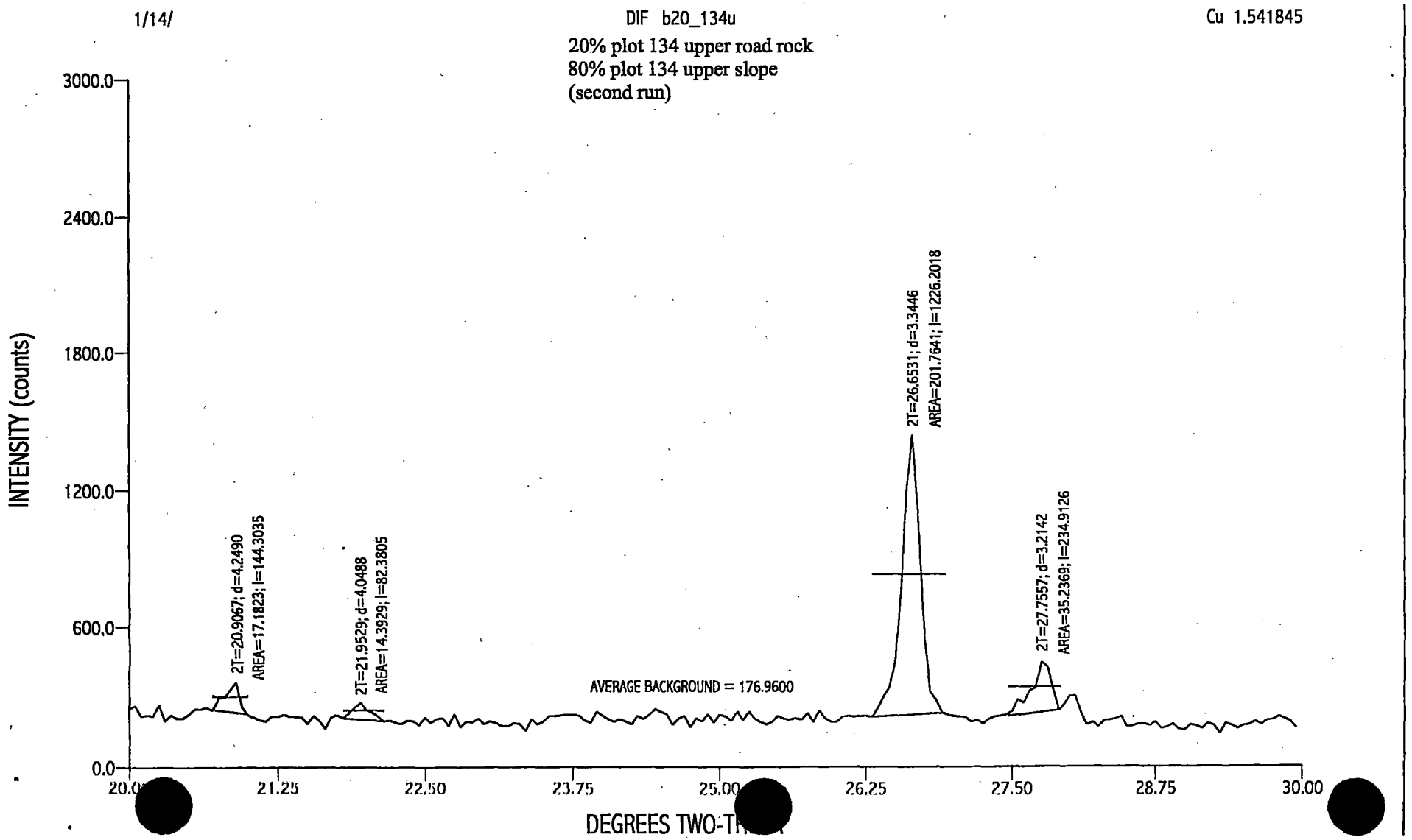
11/04/99

20_134u

Cu 1.541845

20% plot 134 upper road rock
80% plot 134 upper slope



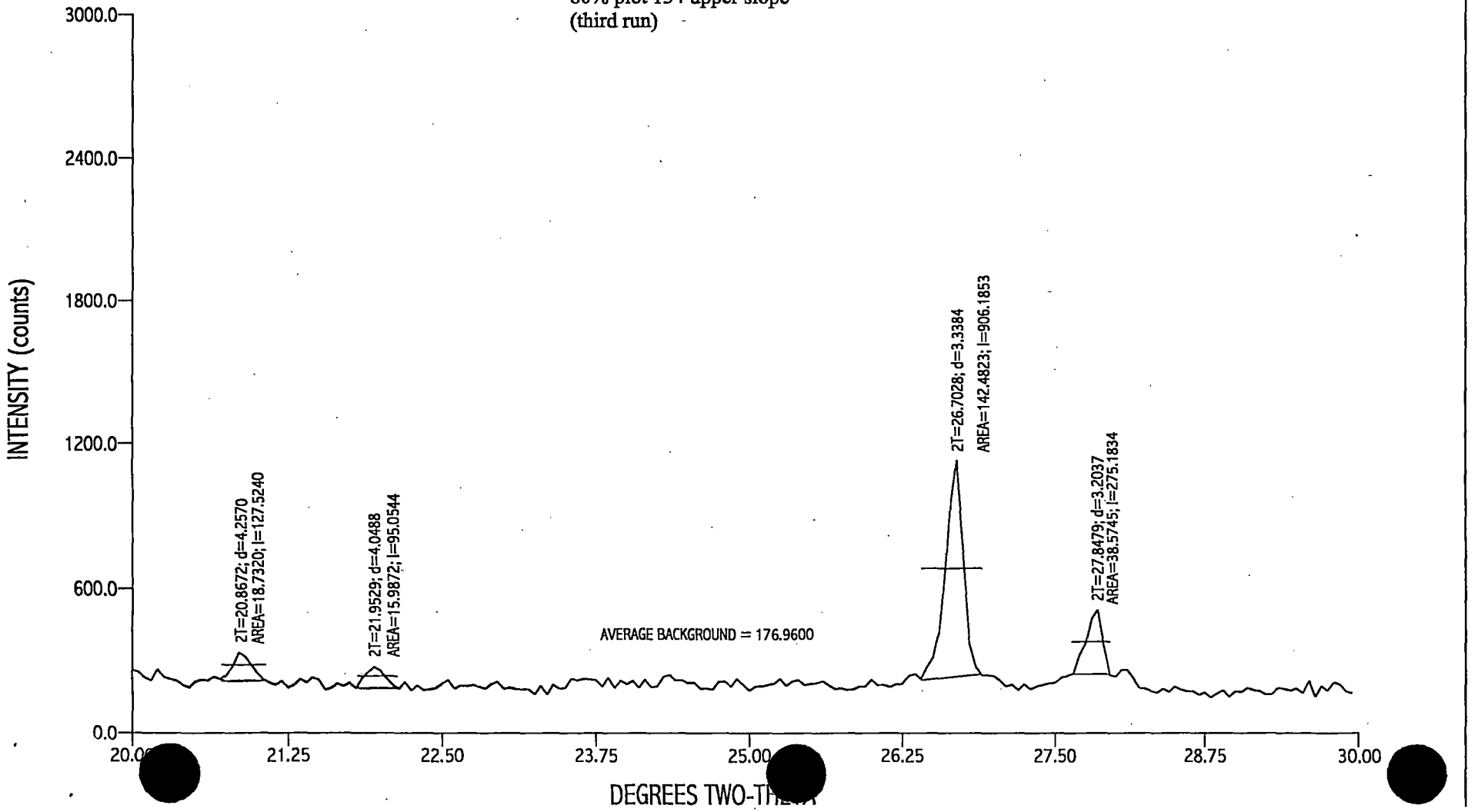

1/14/
DIF b20_134u
Cu 1.541845
20% plot 134 upper road rock
80% plot 134 upper slope
(second run)
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=20.9067; d=4.2490
AREA=17.1823; I=144.3035
2T=21.9529; d=4.0488
AREA=14.3929; I=82.3805
AVERAGE BACKGROUND = 176.9600
2T=26.6531; d=3.3446
AREA=201.7641; I=1226.2018
2T=27.7557; d=3.2142
AREA=35.2369; I=234.9126
20.0
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

1/14/

DIF c20_134u

20% plot 134 upper road rock
80% plot 134 upper slope
(third run)

Cu 1.541845

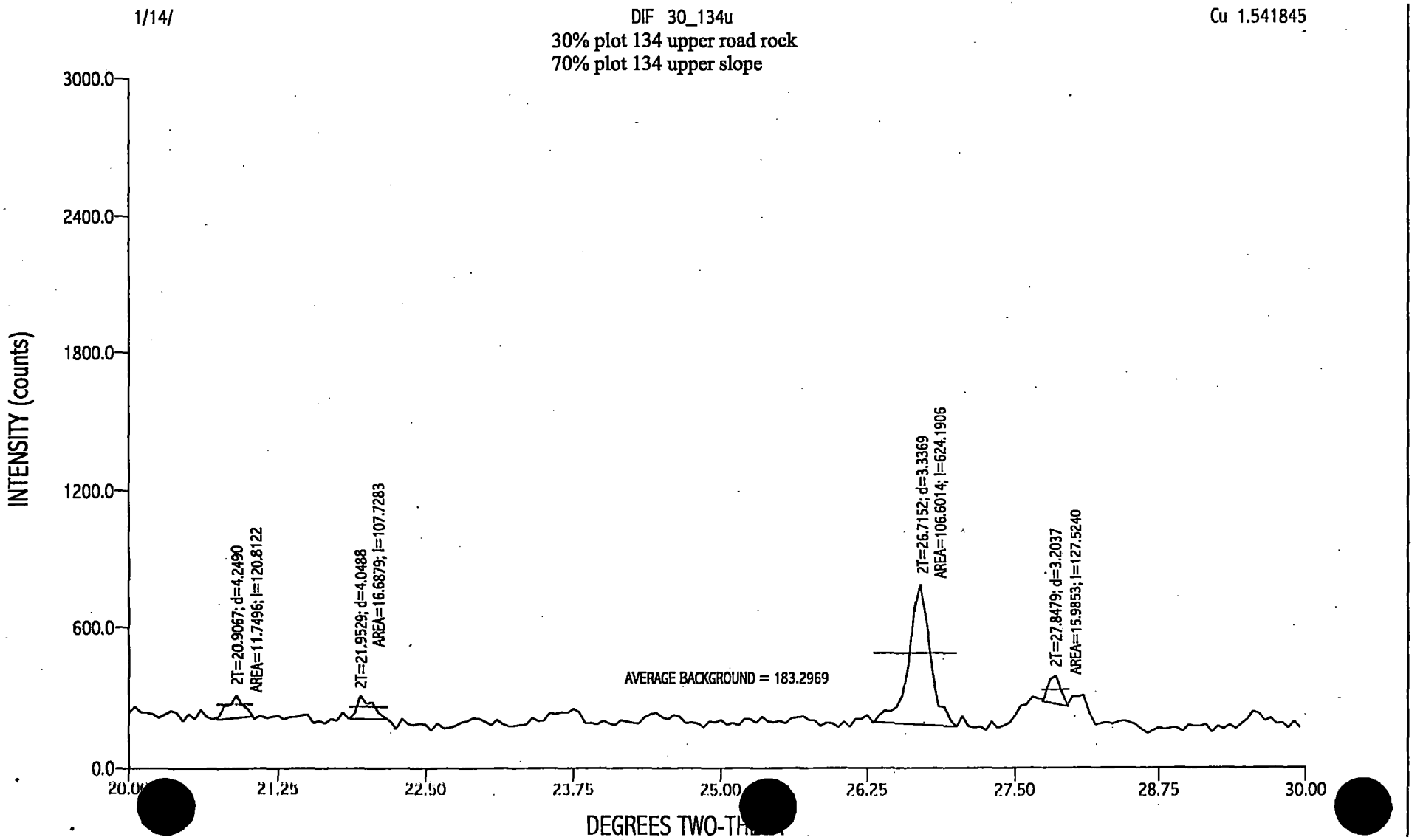


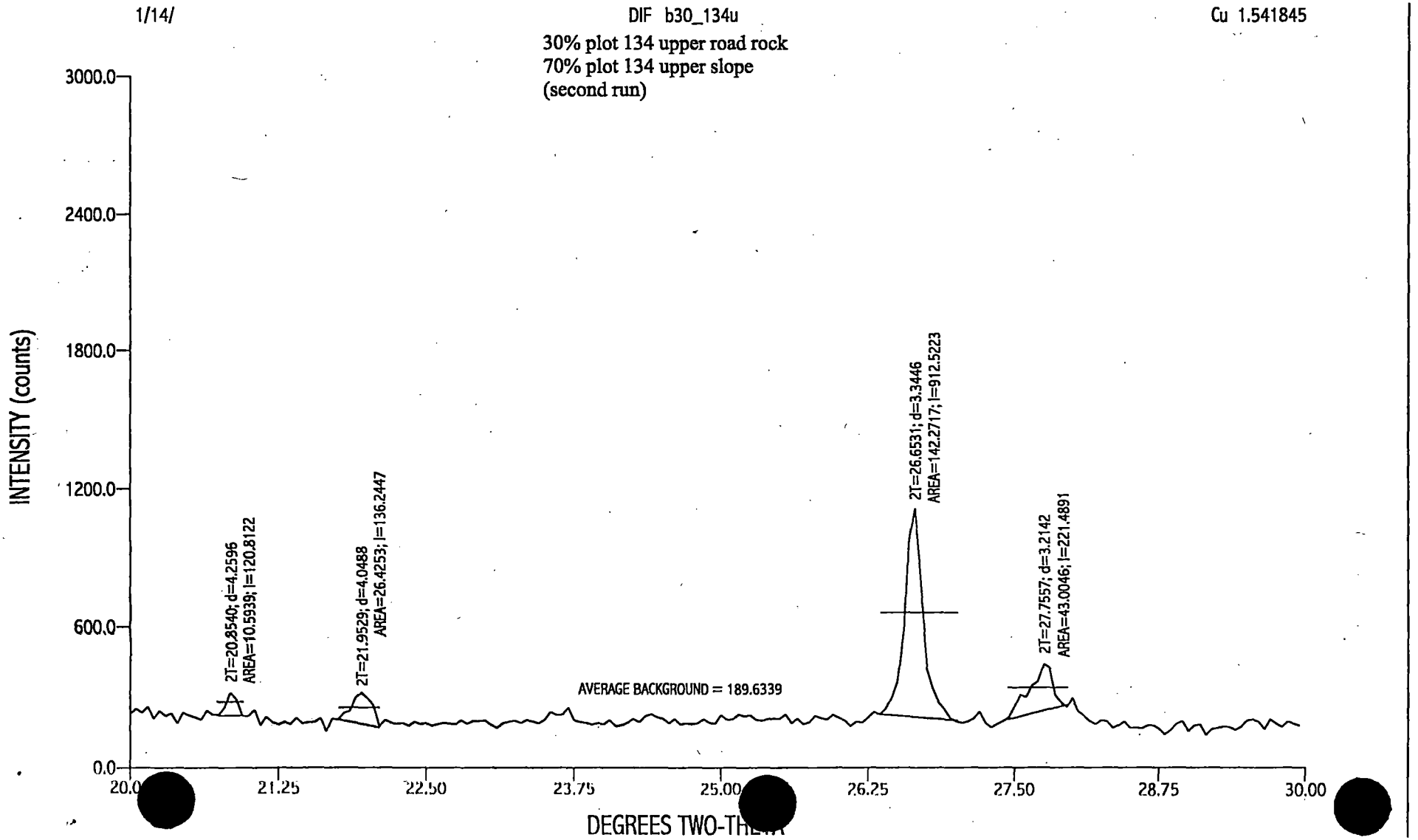
1/14/

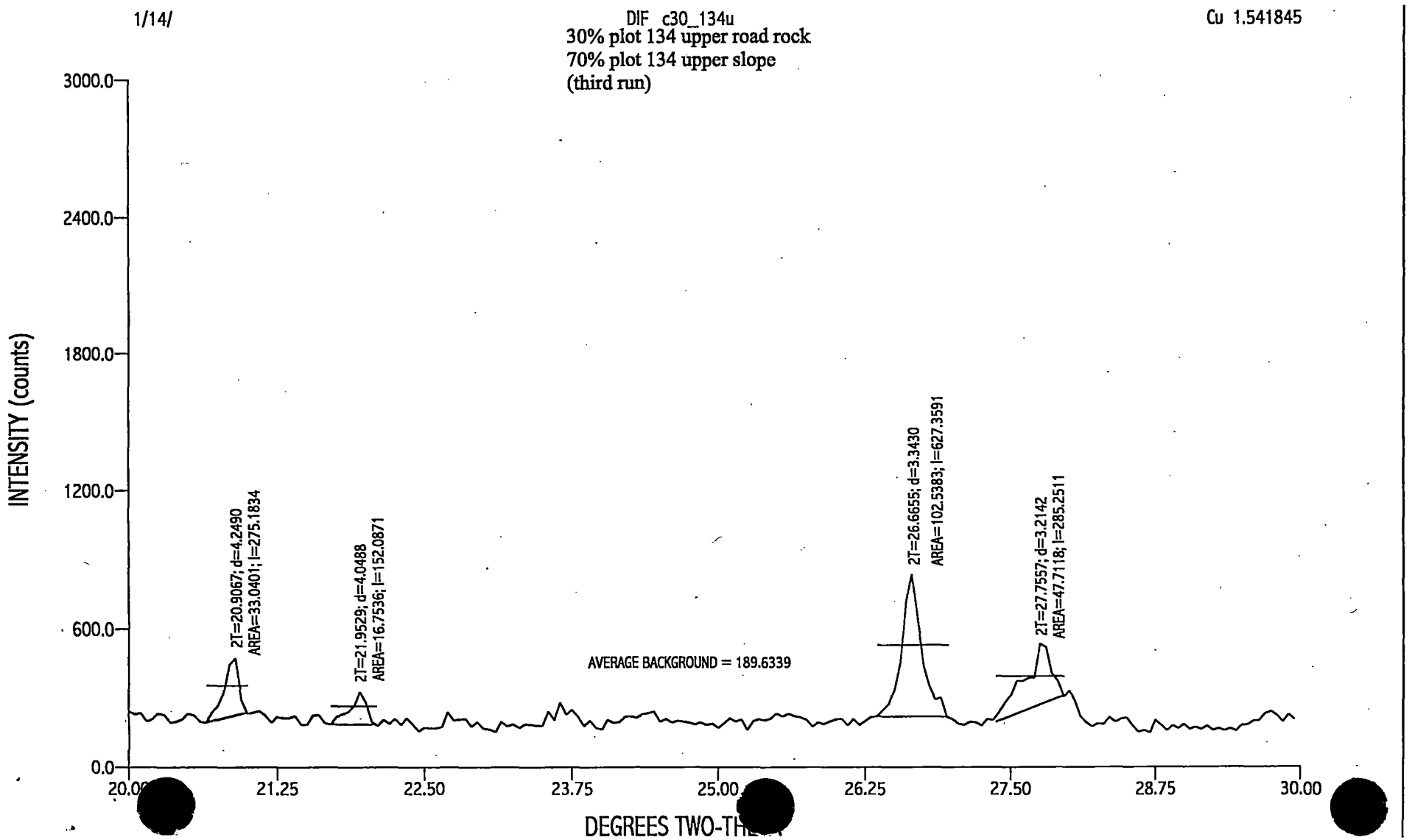
DIF 30_134u

30% plot 134 upper road rock
70% plot 134 upper slope

Cu 1.541845

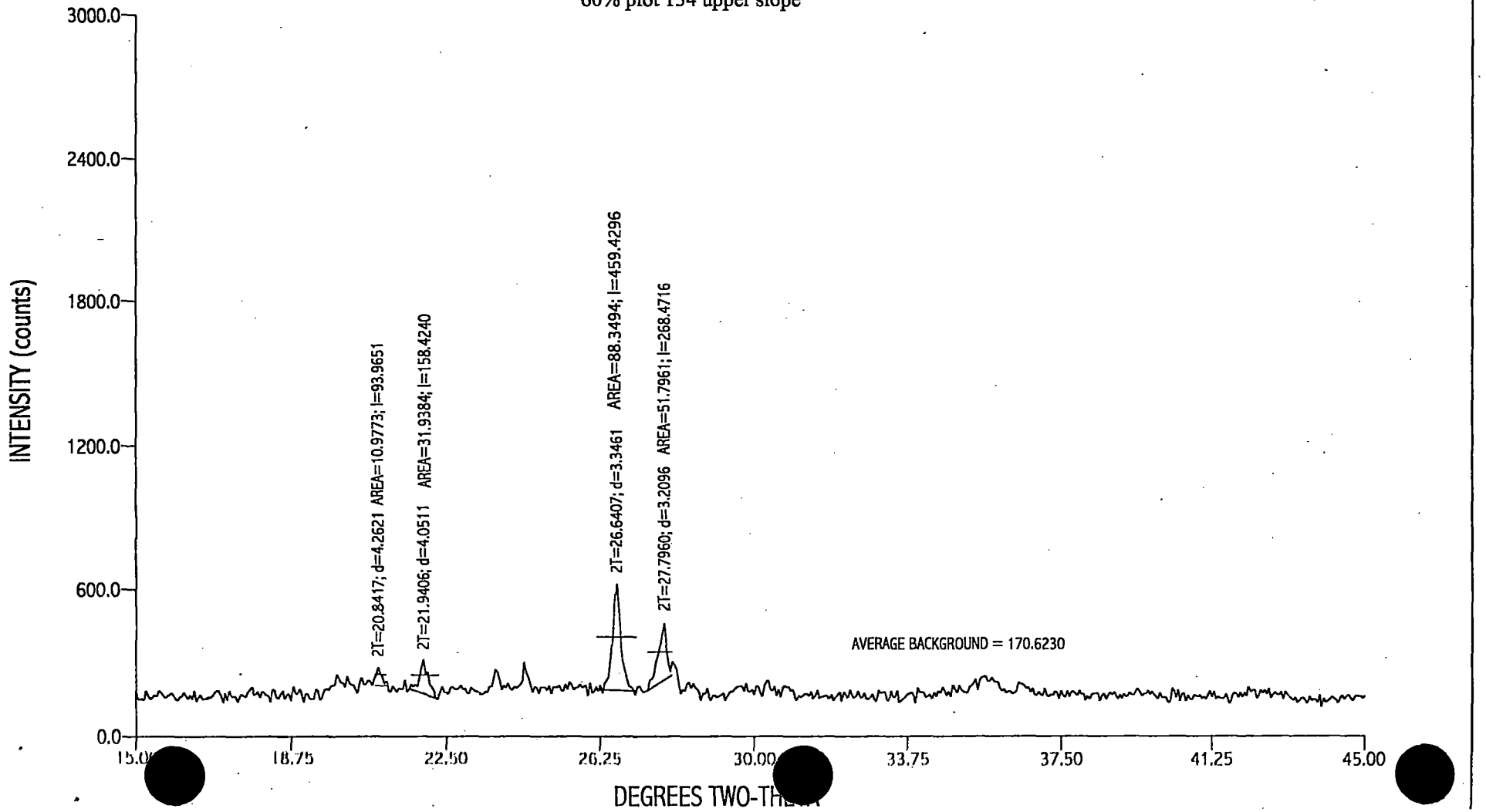



1/14/
DIF b30_134u
Cu 1.541845
30% plot 134 upper road rock
70% plot 134 upper slope
(second run)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8540; d=4.2596
AREA=10.5939; I=120.8122
2T=21.9529; d=4.0488
AREA=26.4253; I=136.2447
2T=26.6531; d=3.3446
AREA=142.2717; I=912.5223
2T=27.7557; d=3.2142
AREA=43.0046; I=221.4891
AVERAGE BACKGROUND = 189.6339
20.0
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THETA


1/14/
DIF c30_134u
30% plot 134 upper road rock
70% plot 134 upper slope
(third run)
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.9067; d=4.2490
AREA=33.0401; I=275.1834
2T=21.9529; d=4.0488
AREA=16.7536; I=152.0871
AVERAGE BACKGROUND = 189.6339
2T=26.6655; d=3.3430
AREA=102.5383; I=627.3591
2T=27.7557; d=3.2142
AREA=47.7118; I=285.2511
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

11/04/99 40_134u Cu 1.541845

40% plot 134 upper road rock
60% plot 134 upper slope

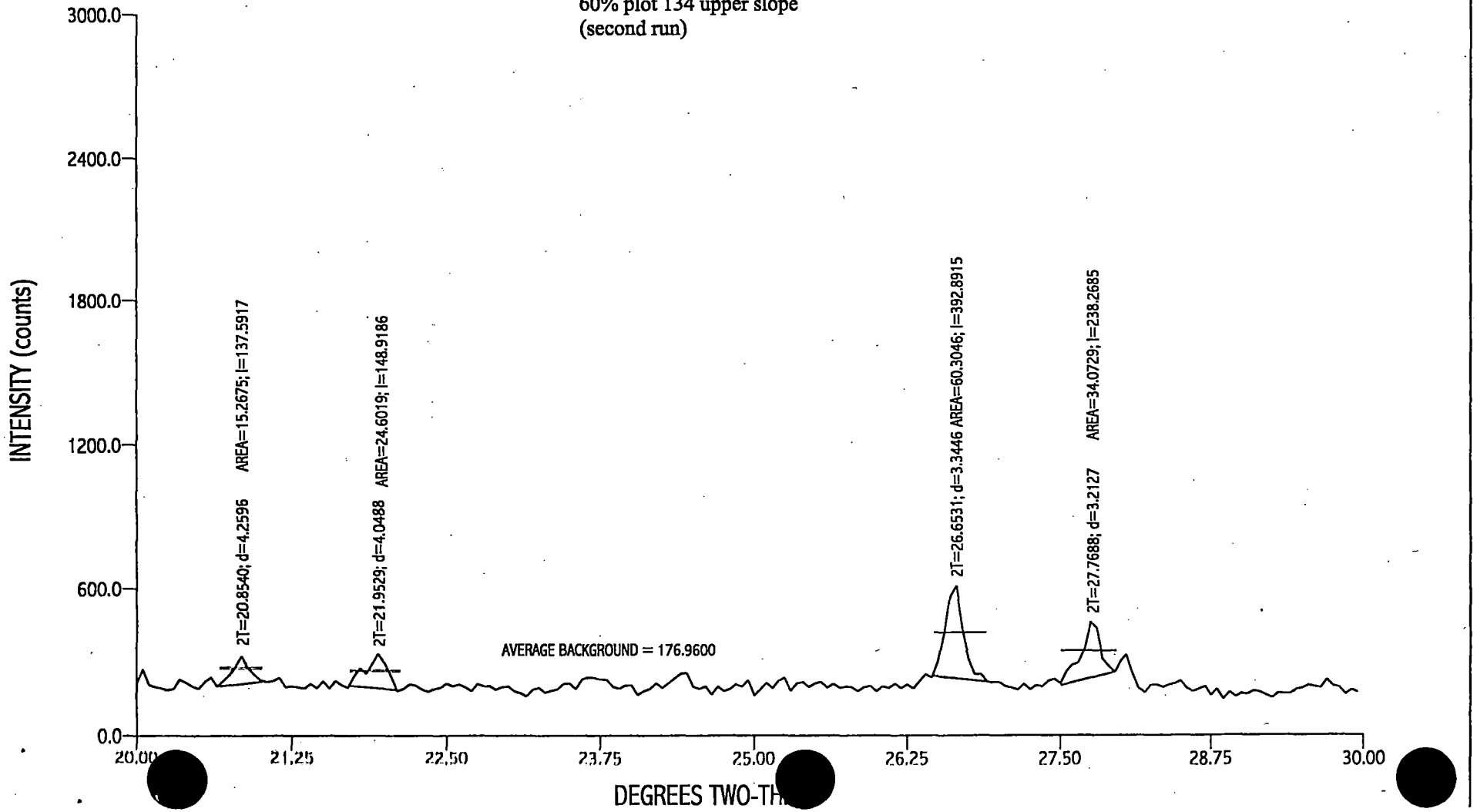


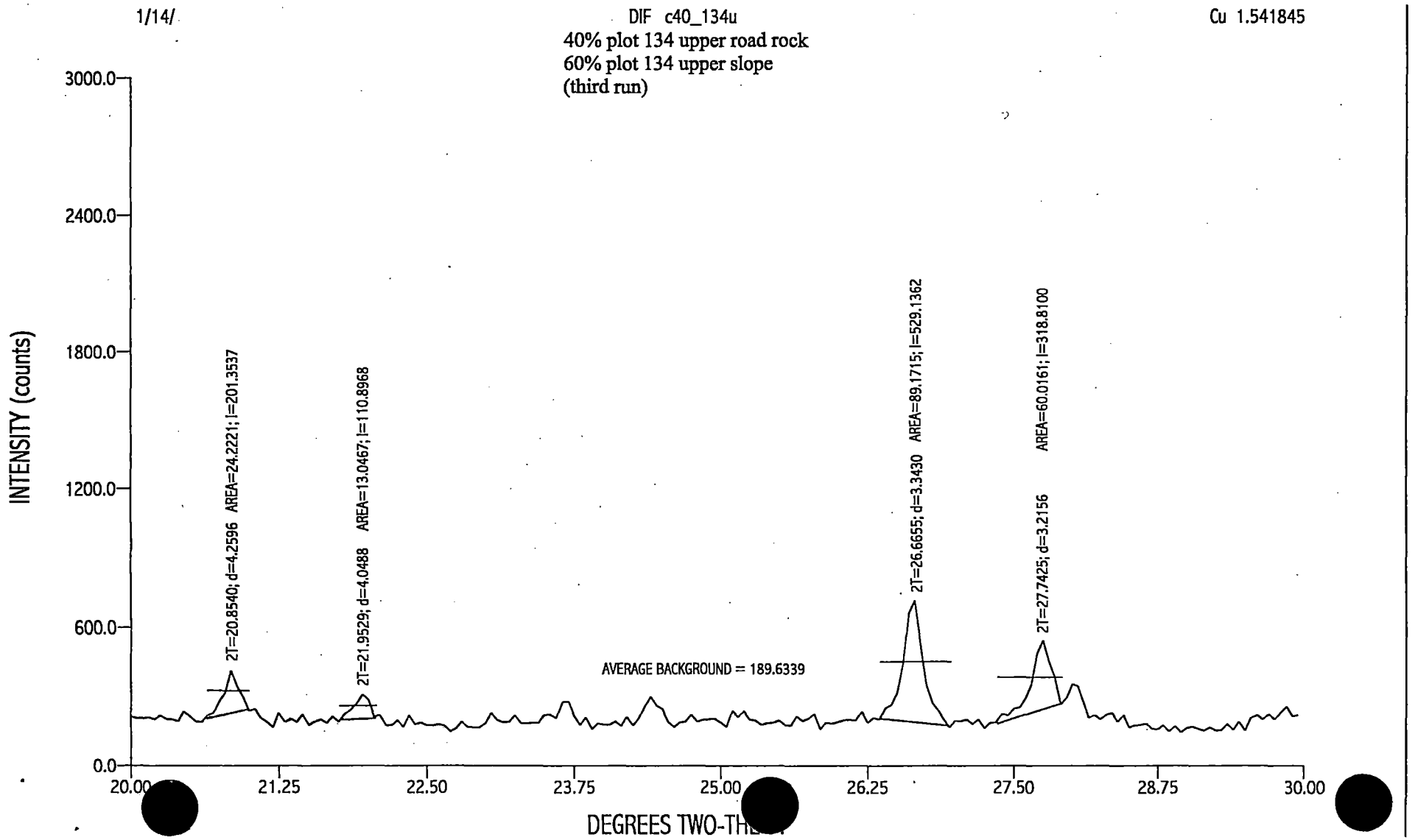
1/14/

DIF b40_134u

Cu 1.541845

40% plot 134 upper road rock
60% plot 134 upper slope
(second run)



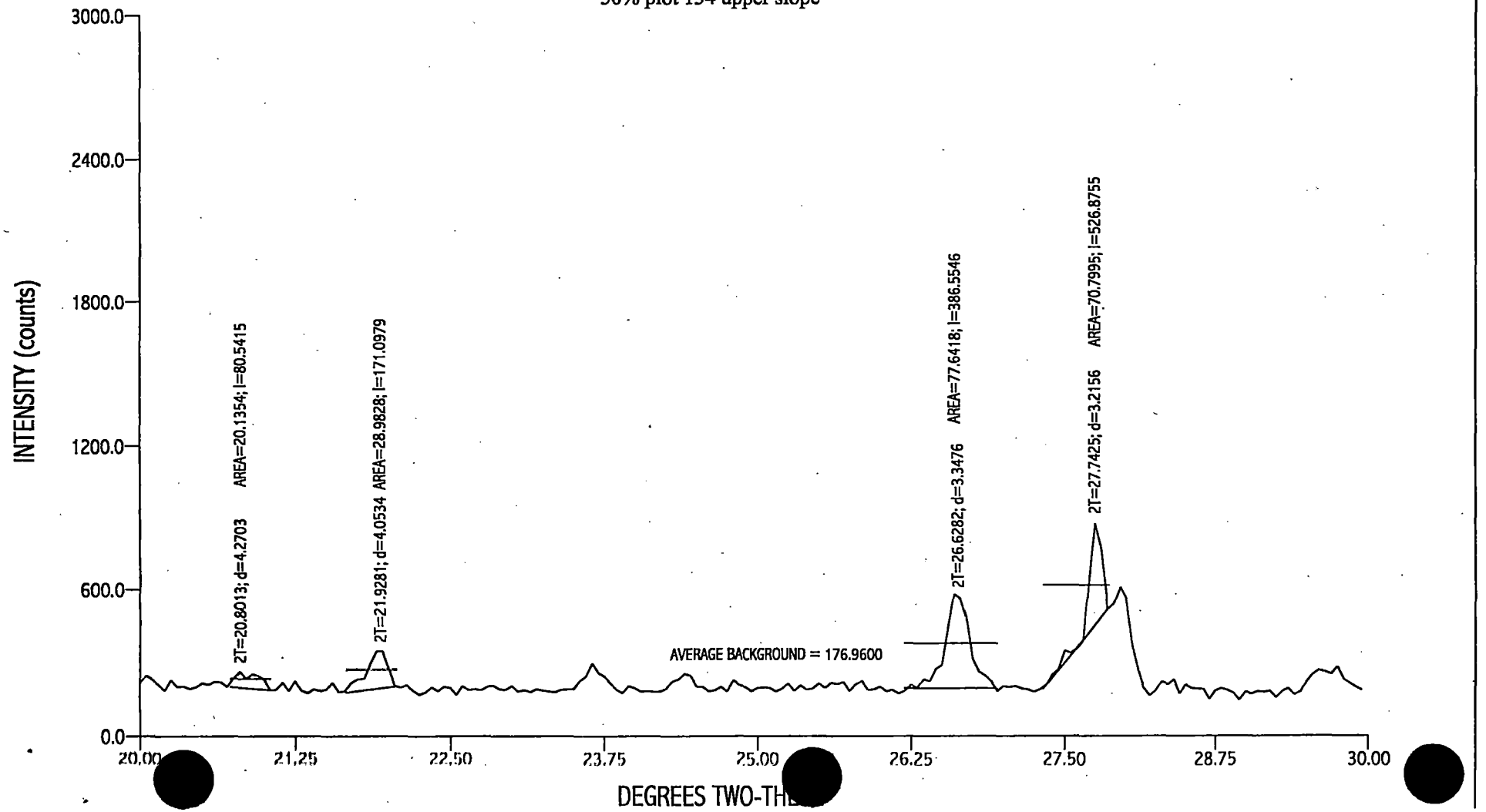

1/14/
DIF c40_134u
Cu 1.541845
40% plot 134 upper road rock
60% plot 134 upper slope
(third run)
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=20.8540; d=4.2596 AREA=24.2221; I=201.3537
2T=21.9529; d=4.0488 AREA=13.0467; I=110.8968
AVERAGE BACKGROUND = 189.6339
2T=26.6655; d=3.3430 AREA=89.1715; I=529.1362
2T=27.7425; d=3.2156 AREA=60.0161; I=318.8100
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

1/14/

DIF 50_134u

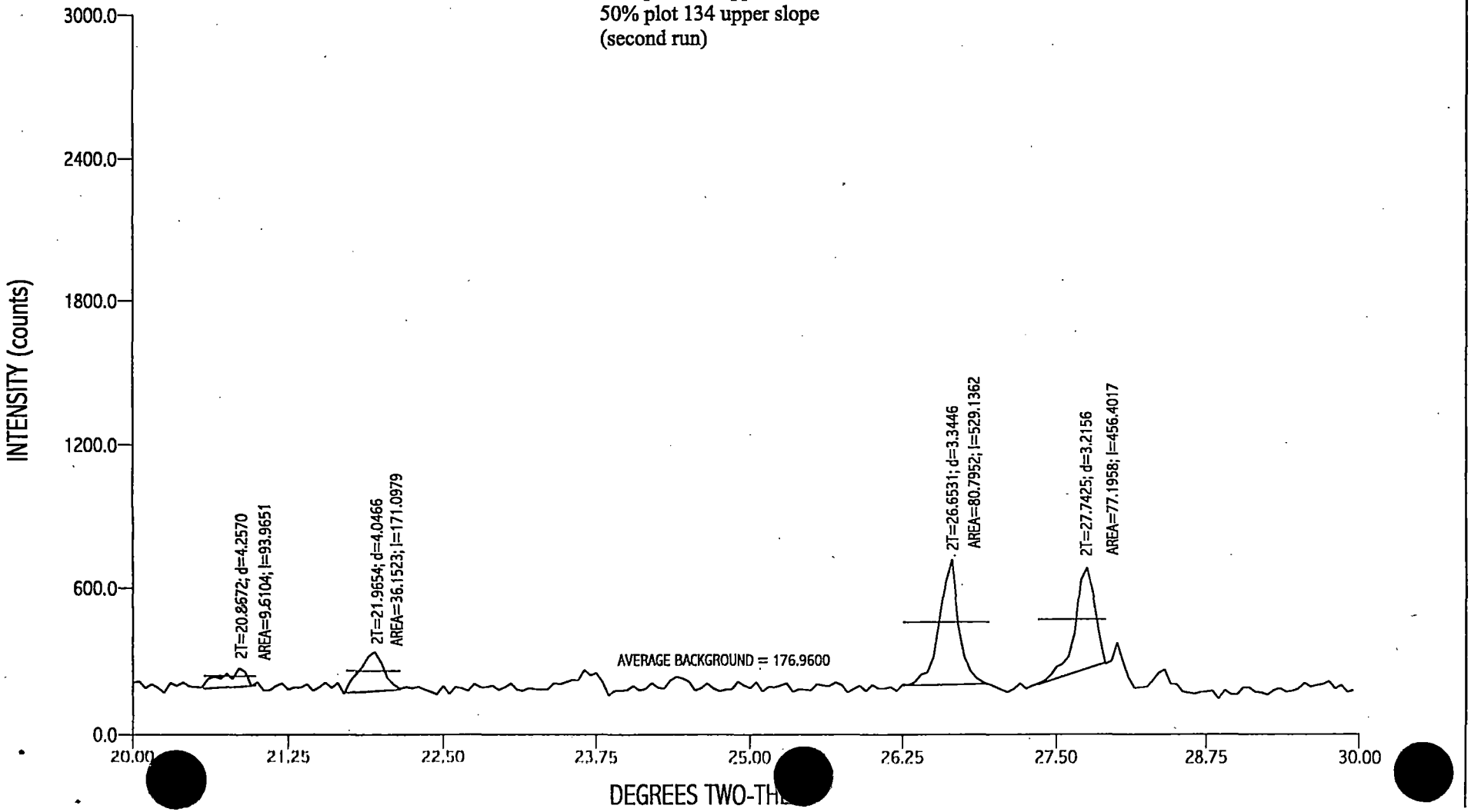
Cu 1.541845

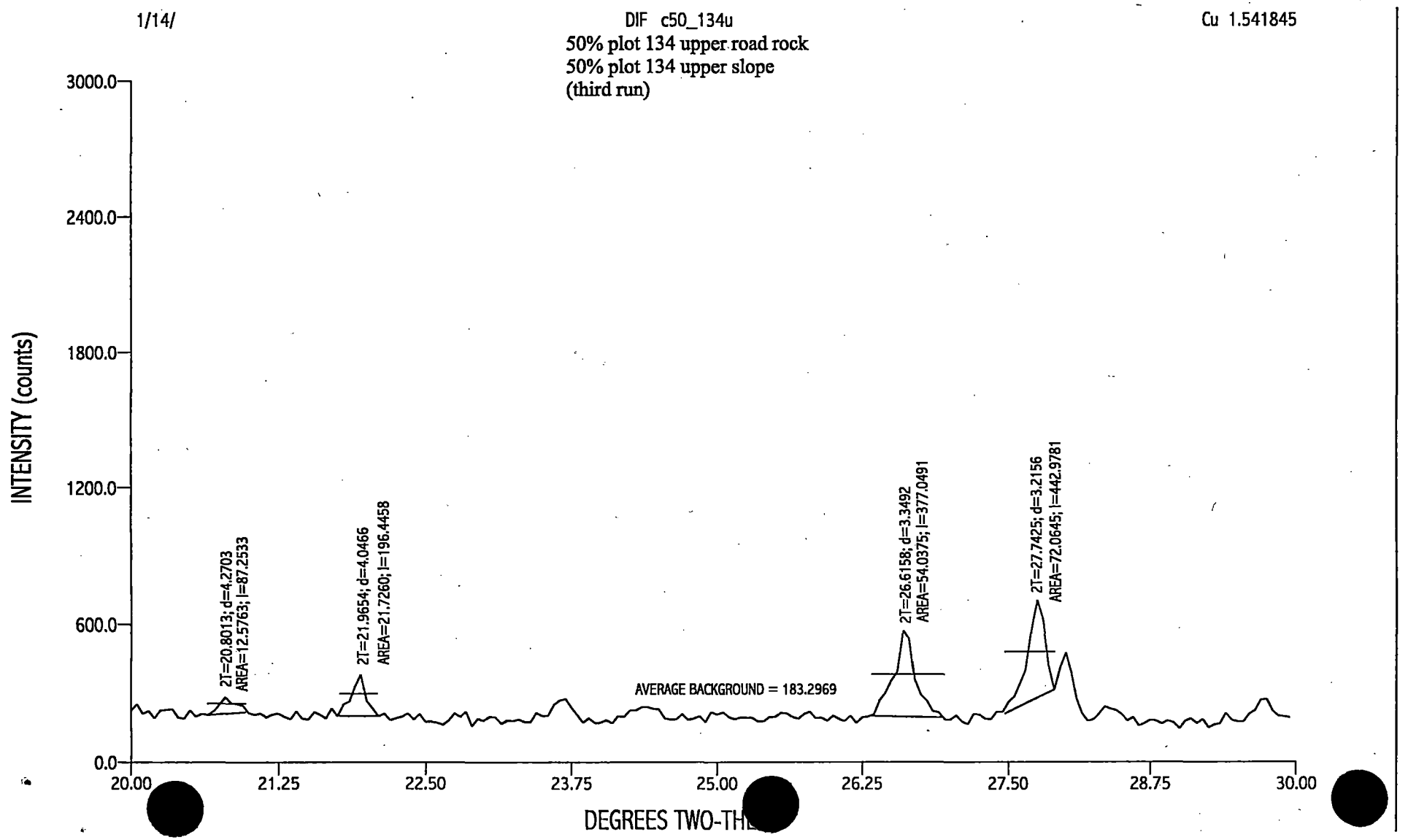
50% plot 134 upper road rock
50% plot 134 upper slope



1/14/ DIF b50_134u Cu 1.541845

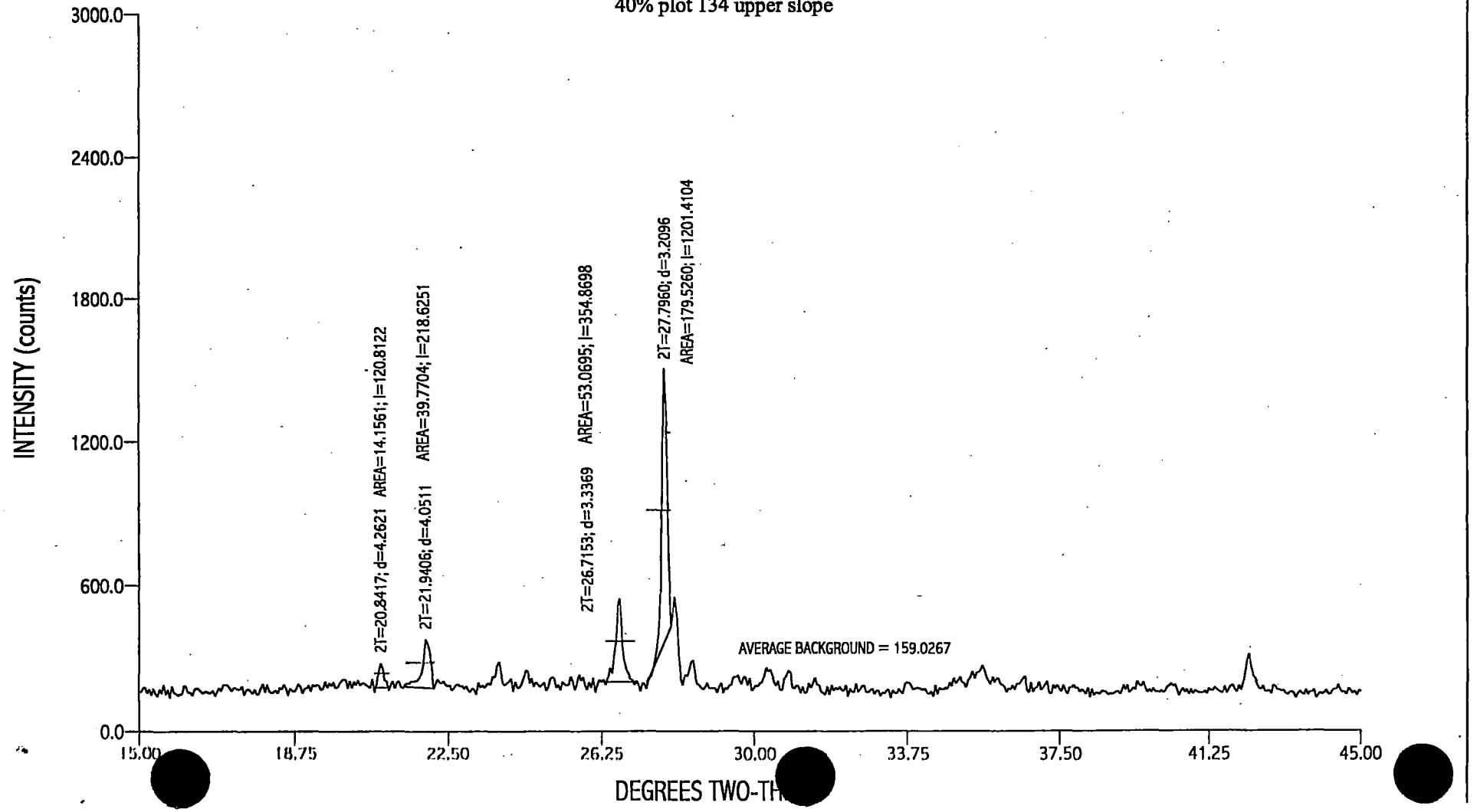
50% plot 134 upper road rock
50% plot 134 upper slope
(second run)

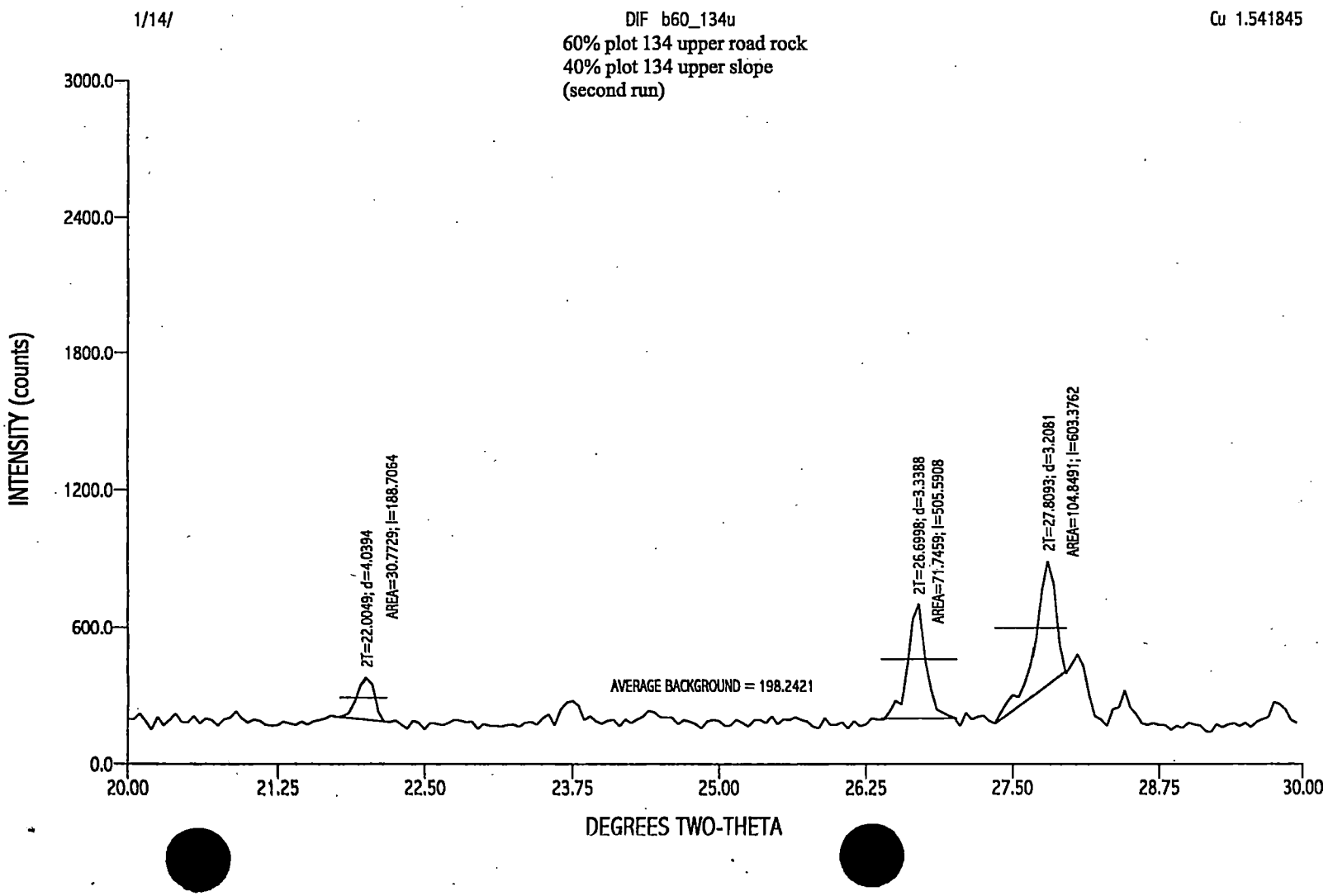


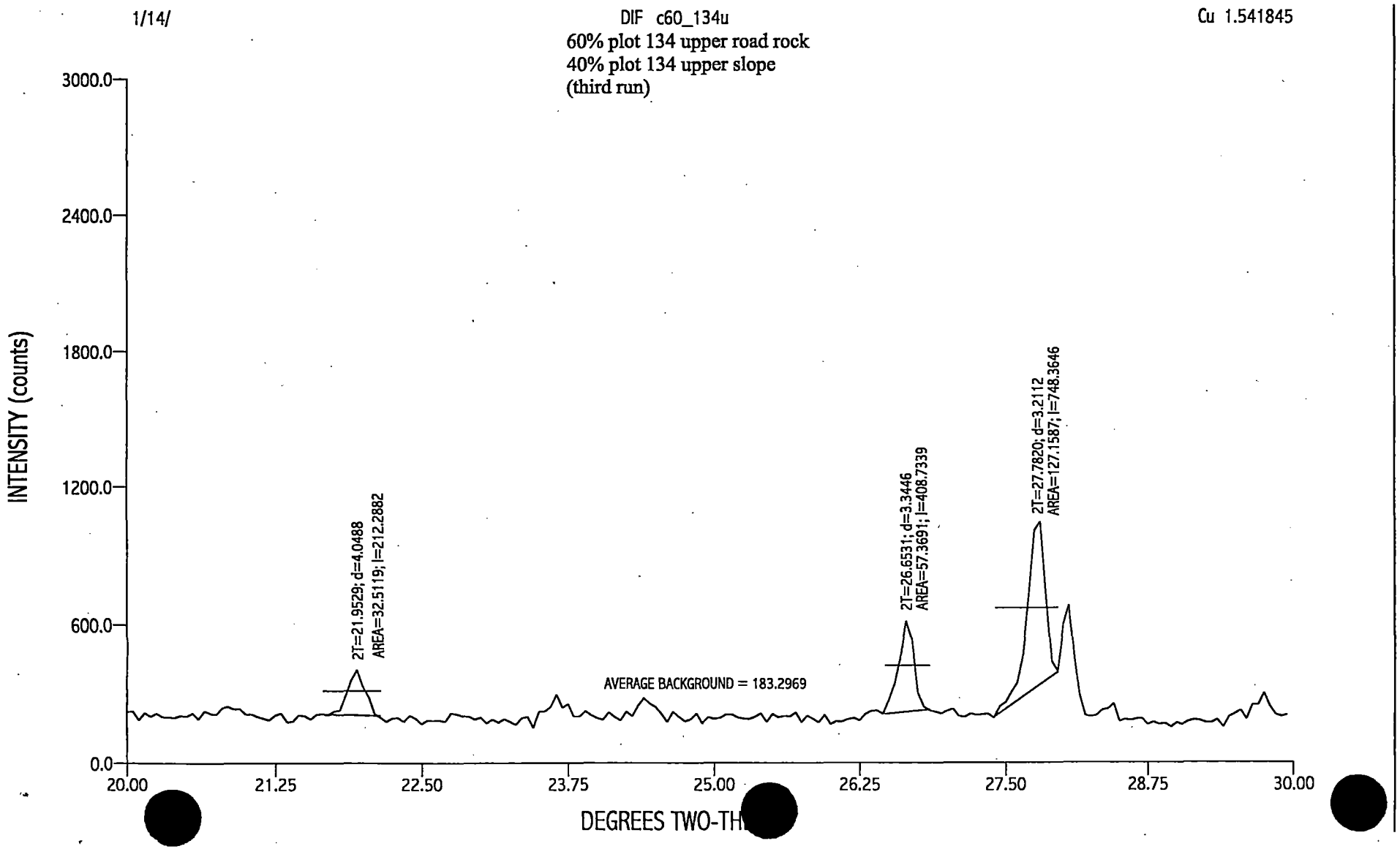

1/14/
DIF c50_134u
Cu 1.541845
50% plot 134 upper road rock
50% plot 134 upper slope
(third run)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8013; d=4.2703
AREA=12.5763; I=87.2533
2T=21.9654; d=4.0466
AREA=21.7260; I=196.4458
AVERAGE BACKGROUND = 183.2969
2T=26.6158; d=3.3492
AREA=54.0375; I=377.0491
2T=27.7425; d=3.2156
AREA=72.0645; I=442.9781
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

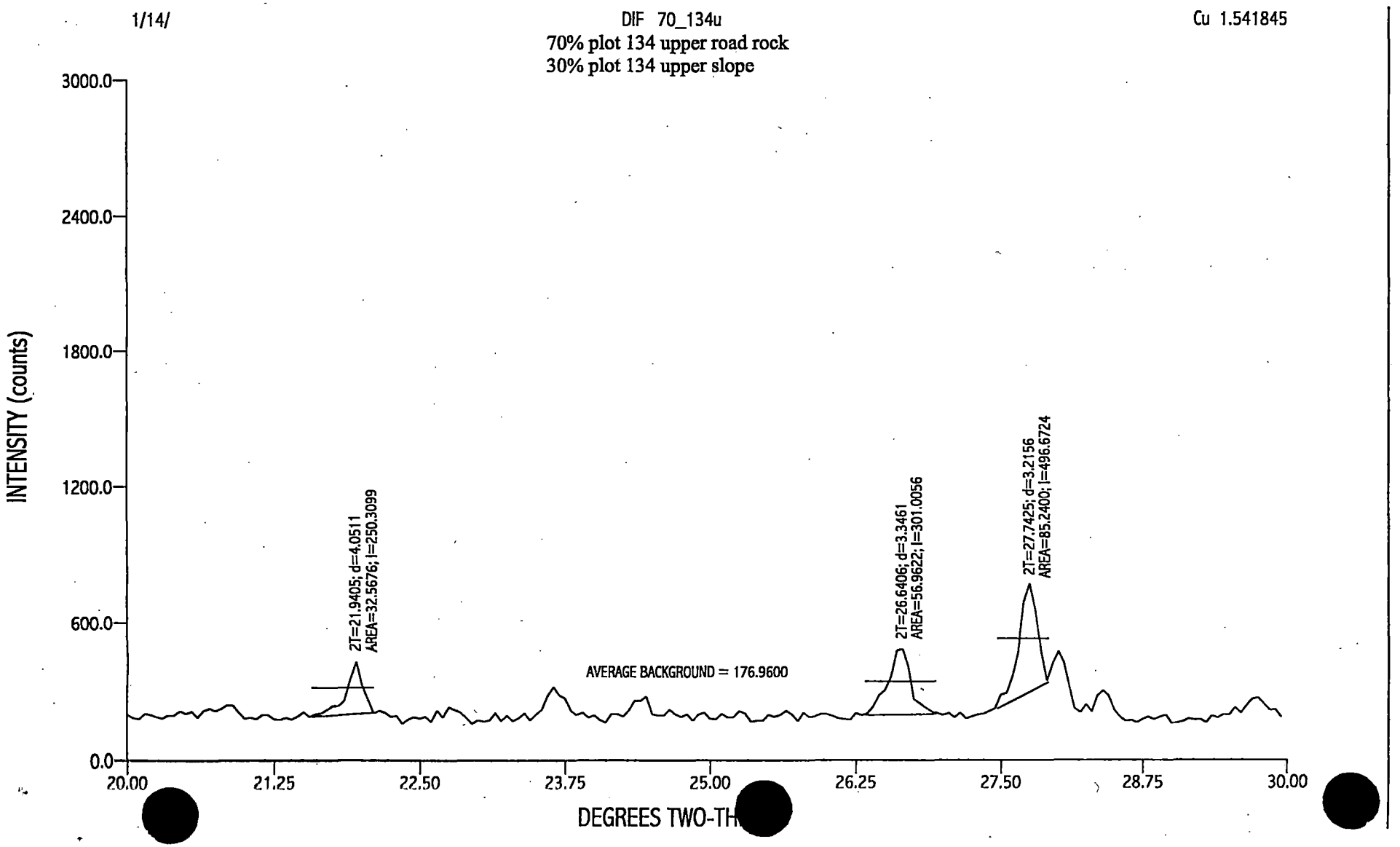
11/04/99 60_134u Cu 1.541845

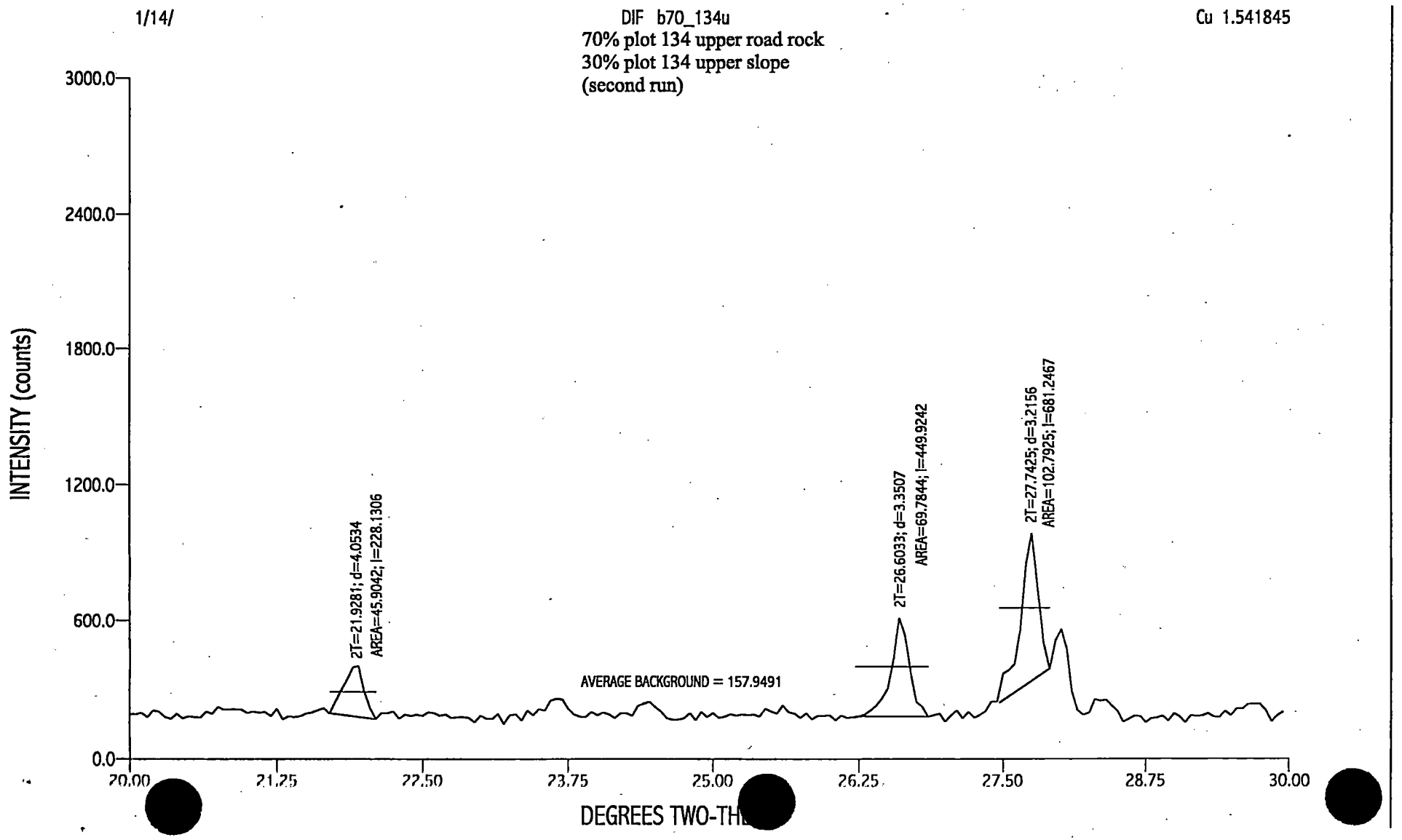
60% plot 134 upper road rock
40% plot 134 upper slope

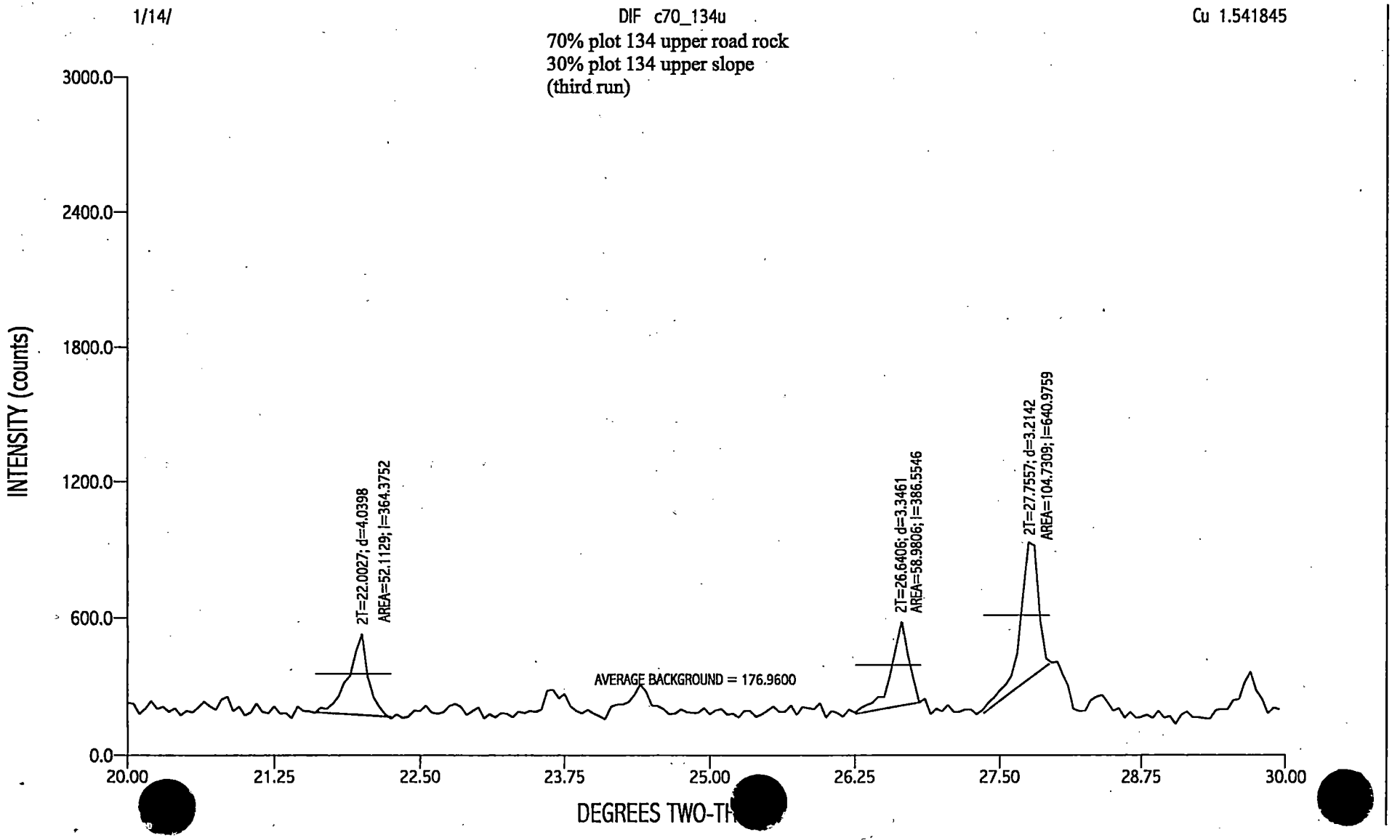


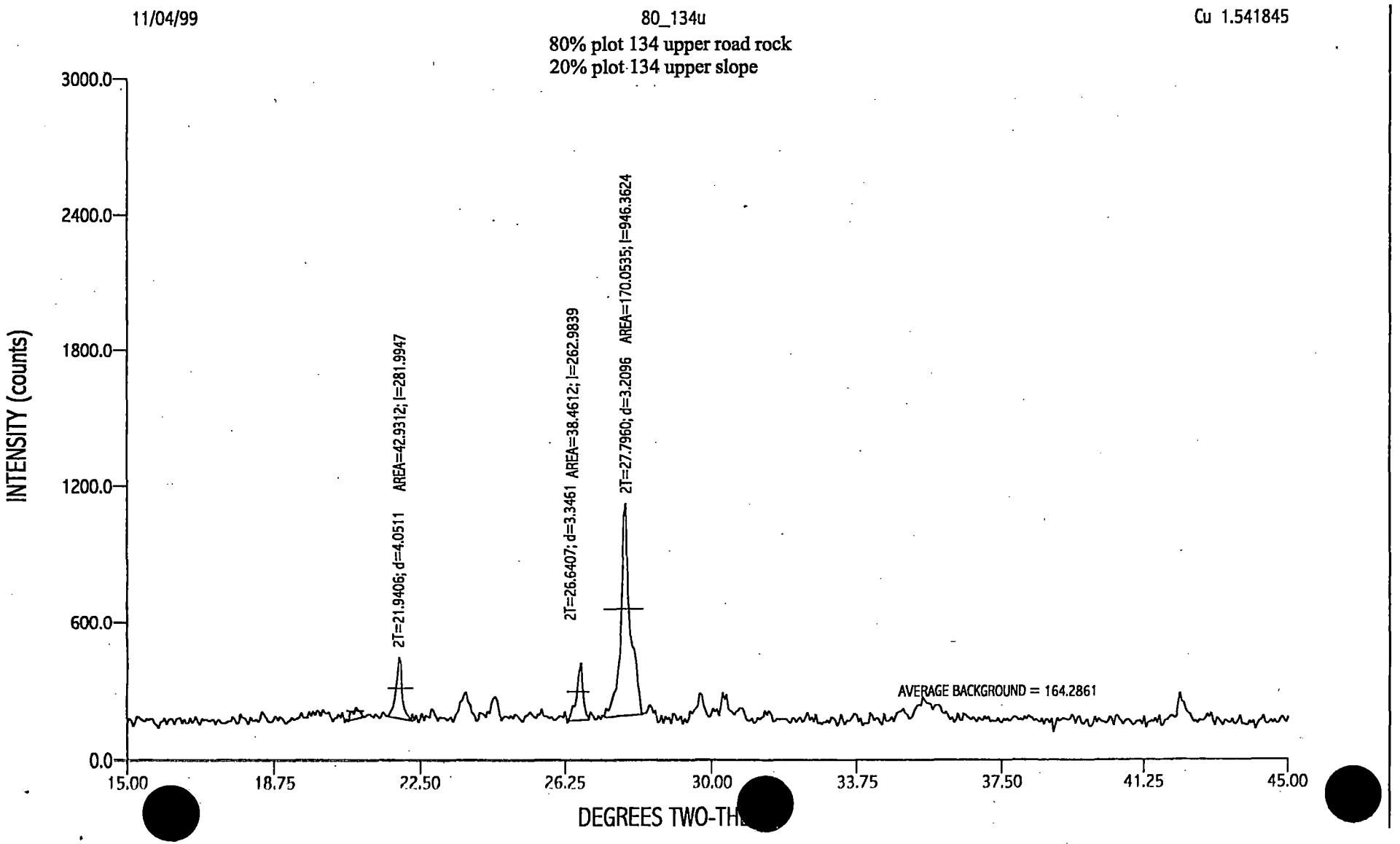

1/14/
DIF b60_134u
60% plot 134 upper road rock
40% plot 134 upper slope
(second run)
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=22.0049; d=4.0394
AREA=30.7729; I=188.7064
AVERAGE BACKGROUND = 198.2421
2T=26.6998; d=3.3388
AREA=71.7459; I=505.5908
2T=27.8093; d=3.2081
AREA=104.8491; I=603.3762
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THETA

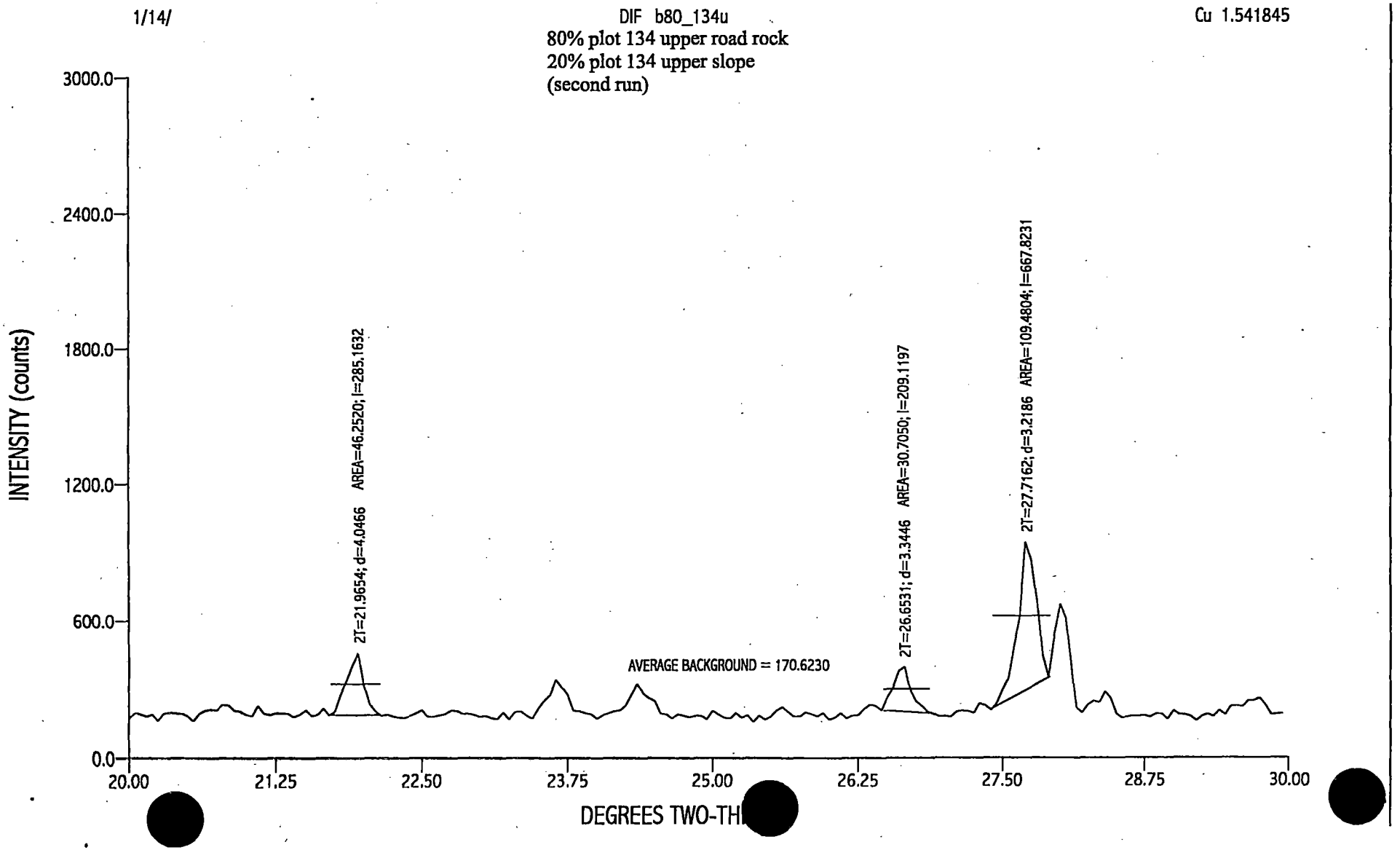

1/14/
DIF c60_134u
60% plot 134 upper road rock
40% plot 134 upper slope
(third run)
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=21.9529; d=4.0488
AREA=32.5119; I=212.2882
AVERAGE BACKGROUND = 183.2969
2T=26.6531; d=3.3446
AREA=57.3691; I=408.7339
2T=27.7820; d=3.2112
AREA=127.1587; I=748.3646
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

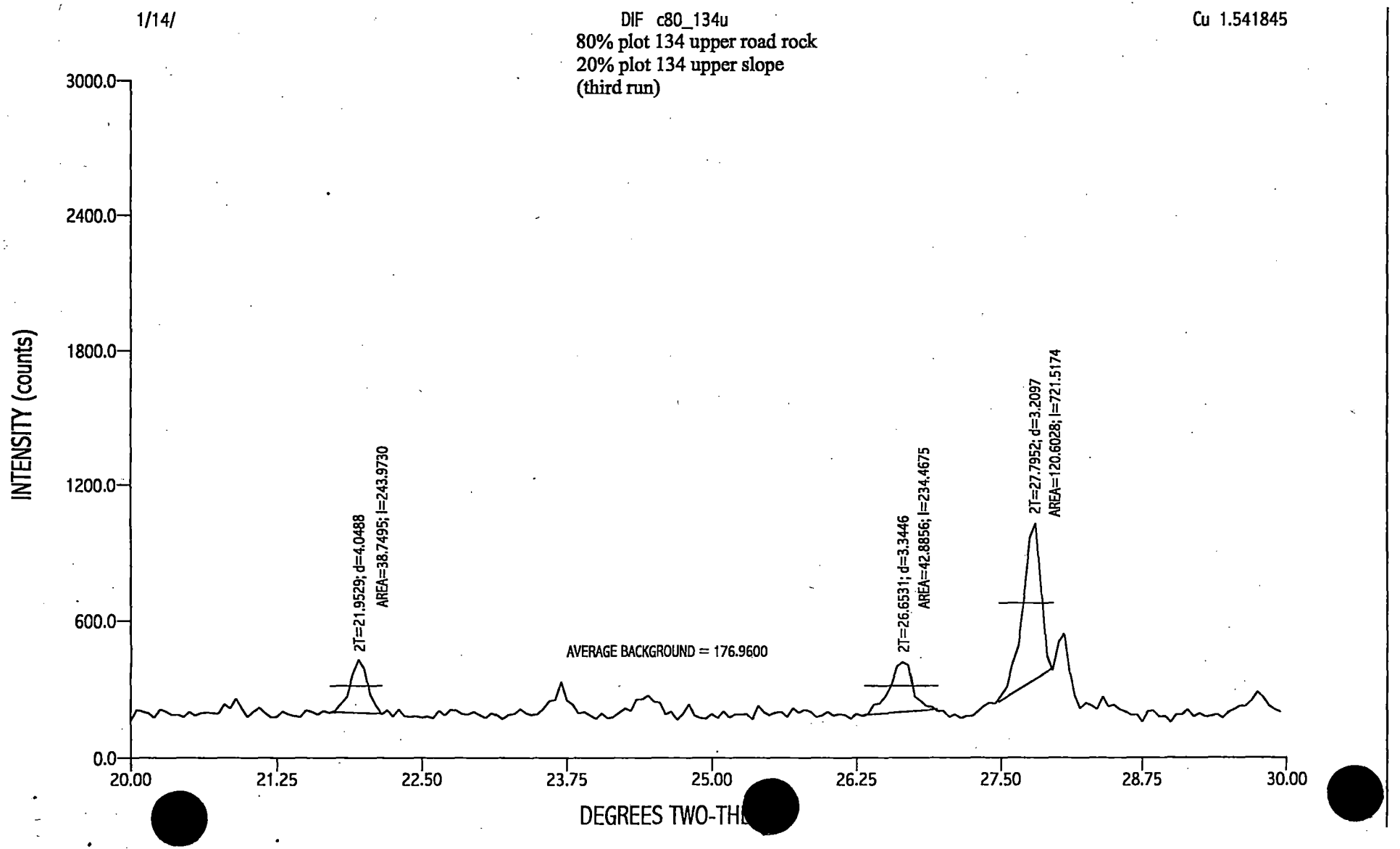

1/14/
DIF 70_134u
70% plot 134 upper road rock
30% plot 134 upper slope
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=21.9405; d=4.0511
AREA=32.5676; I=250.3099
AVERAGE BACKGROUND = 176.9600
2T=26.6406; d=3.3461
AREA=56.9622; I=301.0056
2T=27.7425; d=3.2156
AREA=85.2400; I=496.6724
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

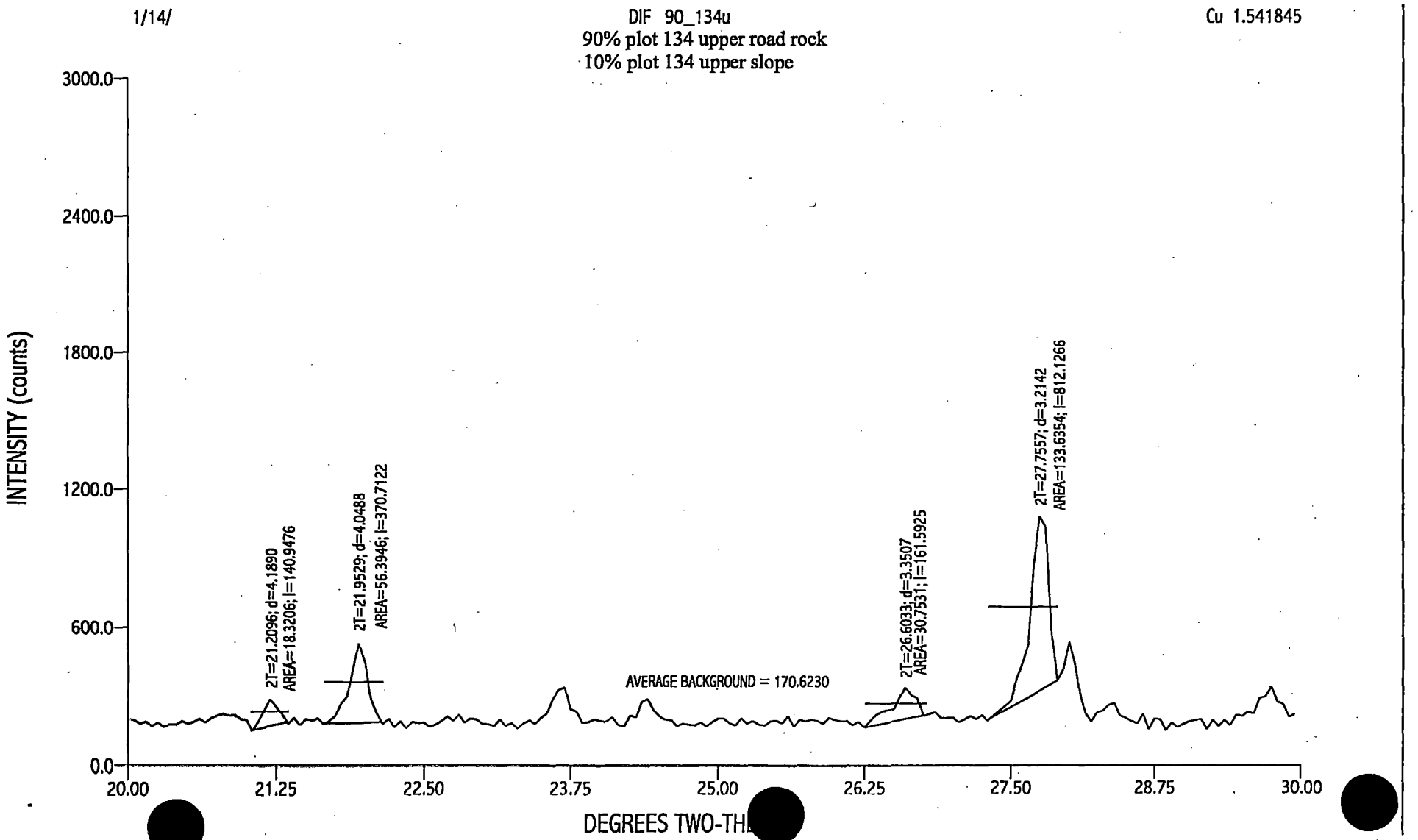

1/14/
DIF b70_134u
70% plot 134 upper road rock
30% plot 134 upper slope
(second run)
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=21.9281; d=4.0534
AREA=45.9042; I=228.1306
2T=26.6033; d=3.3507
AREA=69.7844; I=449.9242
2T=27.7425; d=3.2156
AREA=102.7925; I=681.2467
AVERAGE BACKGROUND = 157.9491
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

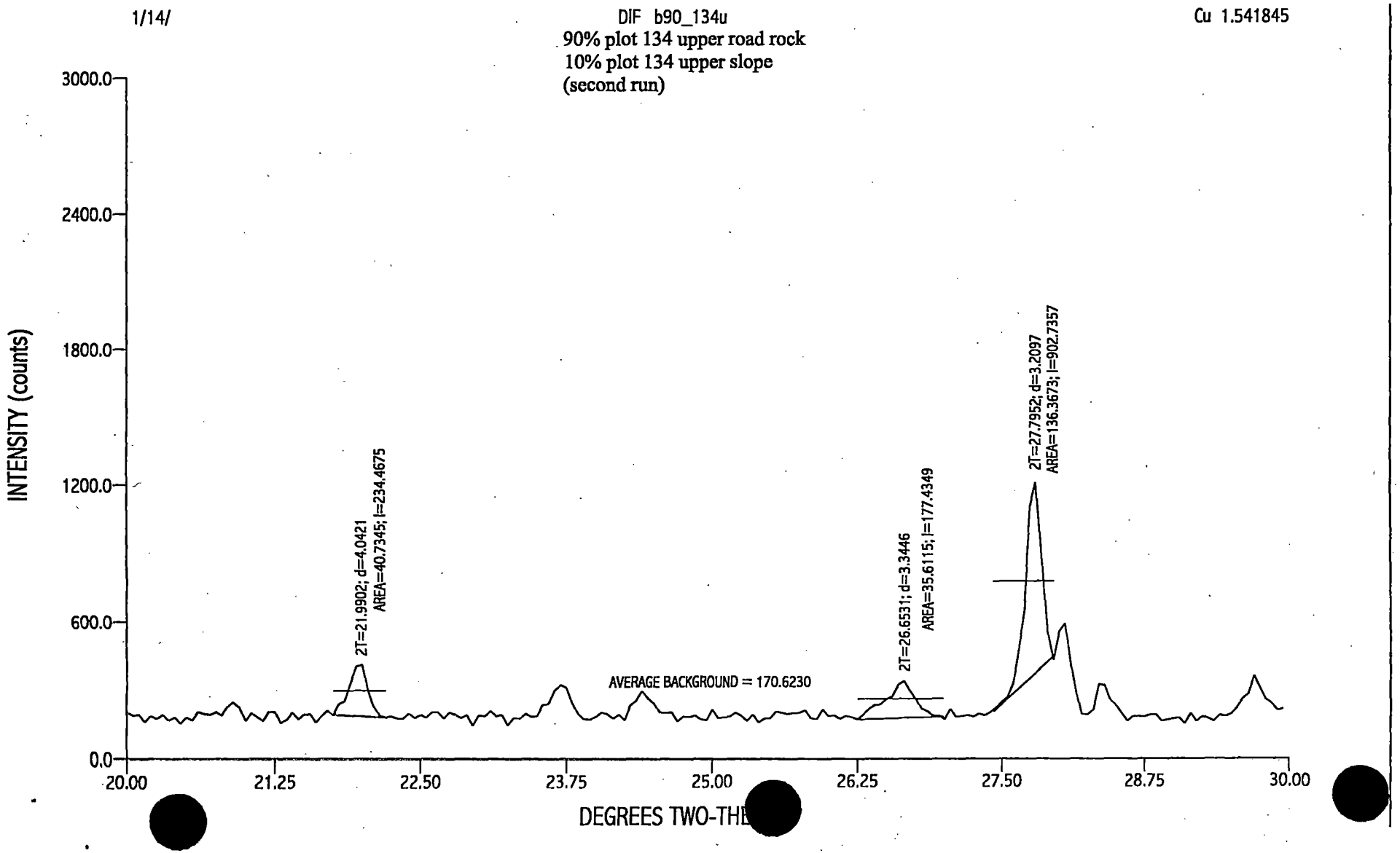

1/14/
DIF c70_134u
70% plot 134 upper road rock
30% plot 134 upper slope
(third run)
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=22.0027; d=4.0398
AREA=52.1129; I=364.3752
2T=26.6406; d=3.3461
AREA=58.9806; I=386.5546
2T=27.7557; d=3.2142
AREA=104.7309; I=640.9759
AVERAGE BACKGROUND = 176.9600
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

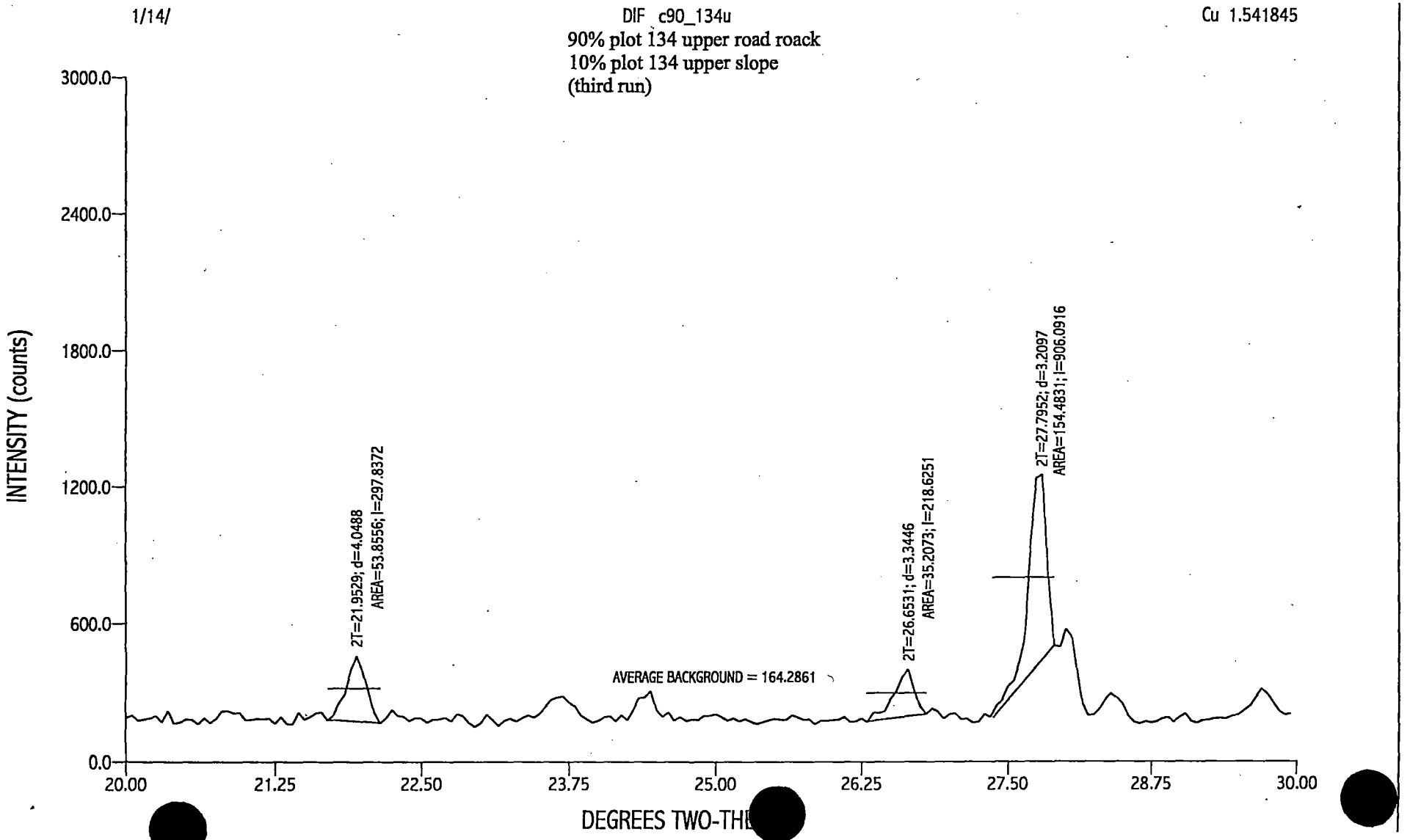

11/04/99
80_134u
Cu 1.541845
80% plot 134 upper road rock
20% plot 134 upper slope
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=21.9406; d=4.0511 AREA=42.9312; I=281.9947
2T=26.6407; d=3.3461 AREA=38.4612; I=262.9839
2T=27.7960; d=3.2096 AREA=170.0535; I=946.3624
AVERAGE BACKGROUND = 164.2861
15.00
18.75
22.50
26.25
30.00
33.75
37.50
41.25
45.00
DEGREES TWO-TH

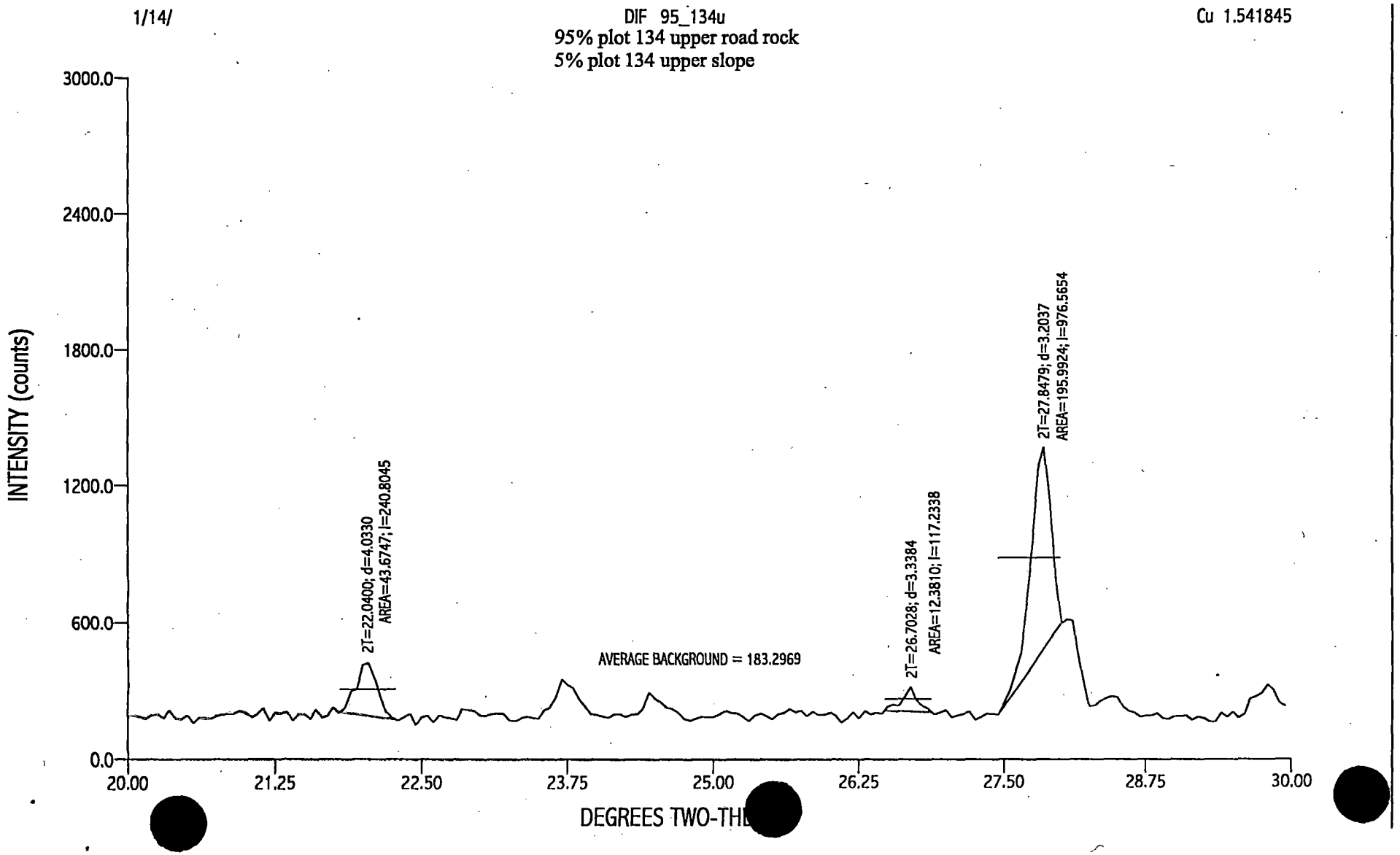

1/14/
DIF b80_134u
80% plot 134 upper road rock
20% plot 134 upper slope
(second run)
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=21.9654; d=4.0466 AREA=46.2520; I=285.1632
AVERAGE BACKGROUND = 170.6230
2T=26.6531; d=3.3446 AREA=30.7050; I=209.1197
2T=27.7162; d=3.2186 AREA=109.4804; I=667.8231
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

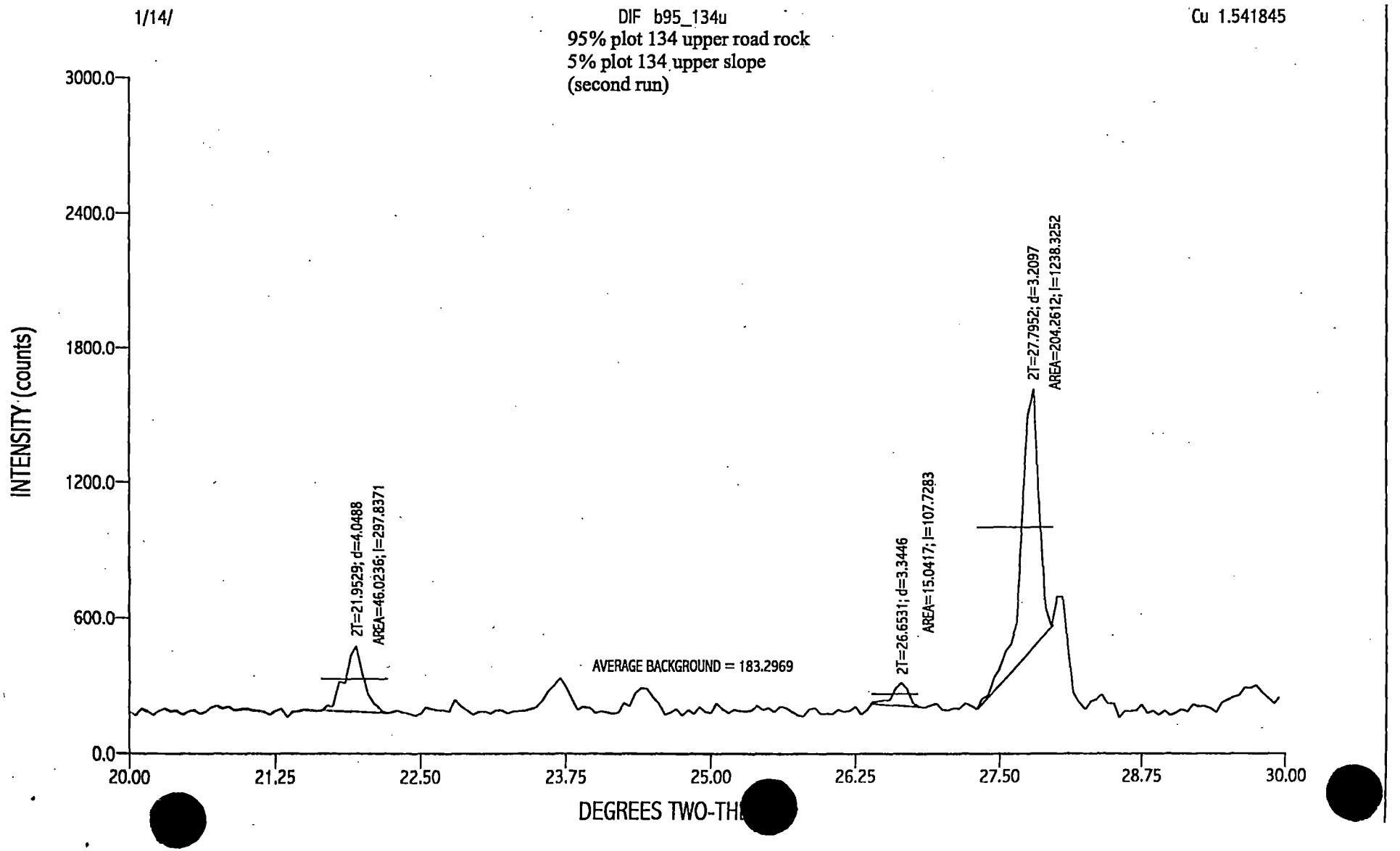

1/14/
DIF c80_134u
80% plot 134 upper road rock
20% plot 134 upper slope
(third run)
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=21.9529; d=4.0488
AREA=38.7495; I=243.9730
AVERAGE BACKGROUND = 176.9600
2T=26.6531; d=3.3446
AREA=42.8856; I=234.4675
2T=27.7952; d=3.2097
AREA=120.6028; I=721.5174
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

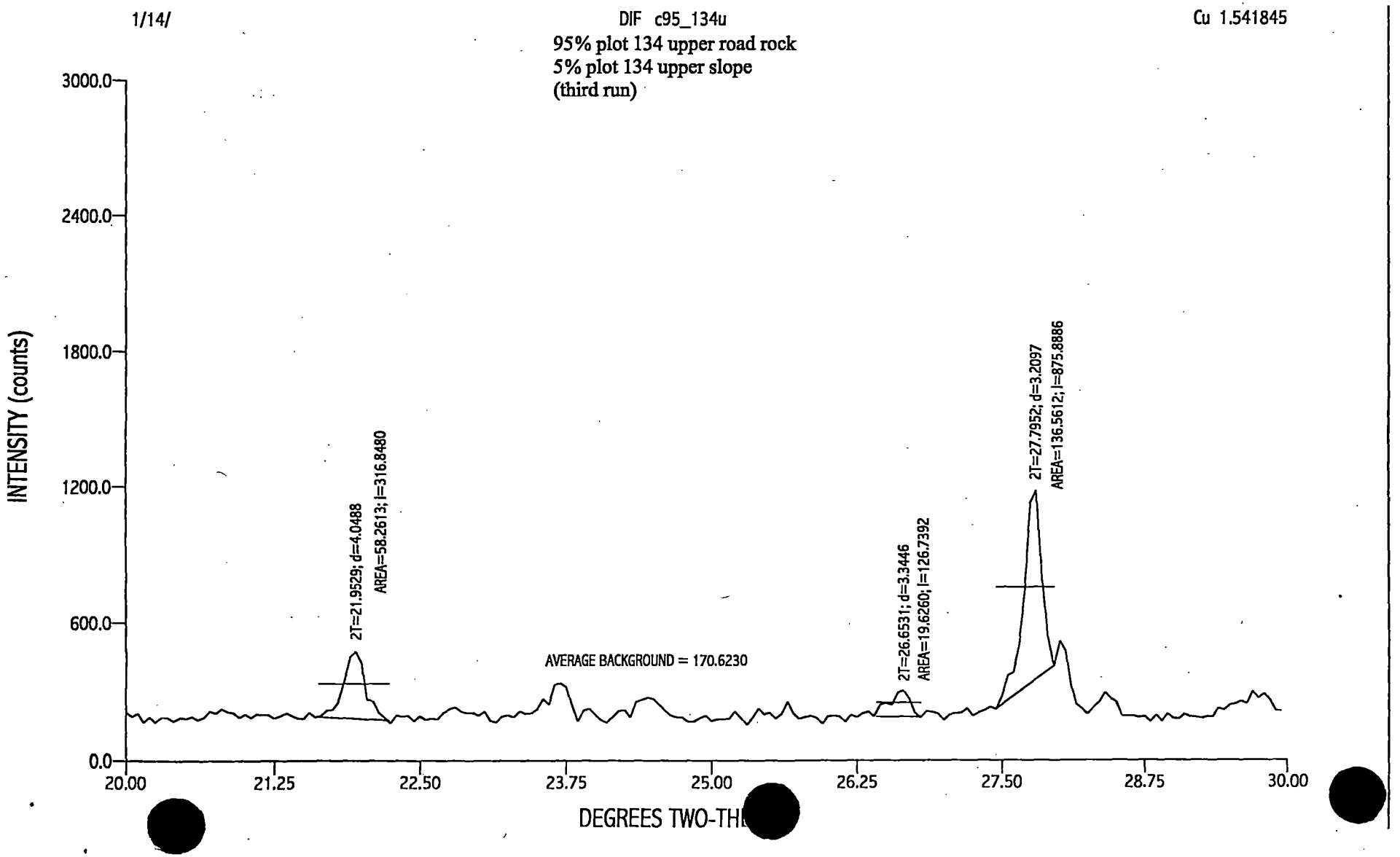

1/14/
DIF 90_134u
90% plot 134 upper road rock
10% plot 134 upper slope
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=21.2096; d=4.1890
AREA=18.3206; I=140.9476
2T=21.9529; d=4.0488
AREA=56.3946; I=370.7122
AVERAGE BACKGROUND = 170.6230
2T=26.6033; d=3.3507
AREA=30.7531; I=161.5925
2T=27.7557; d=3.2142
AREA=133.6354; I=812.1266
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH


1/14/
DIF b90_134u
90% plot 134 upper road rock
10% plot 134 upper slope
(second run)
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=21.9902; d=4.0421
AREA=40.7345; I=234.4675
AVERAGE BACKGROUND = 170.6230
2T=26.6531; d=3.3446
AREA=35.6115; I=177.4349
2T=27.7952; d=3.2097
AREA=136.3673; I=902.7357
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE


1/14/
DIF c90_134u
90% plot 134 upper road roack
10% plot 134 upper slope
(third run)
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=21.9529; d=4.0488
AREA=53.8556; I=297.8372
AVERAGE BACKGROUND = 164.2861
2T=26.6531; d=3.3446
AREA=35.2073; I=218.6251
2T=27.7952; d=3.2097
AREA=154.4831; I=906.0916
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE

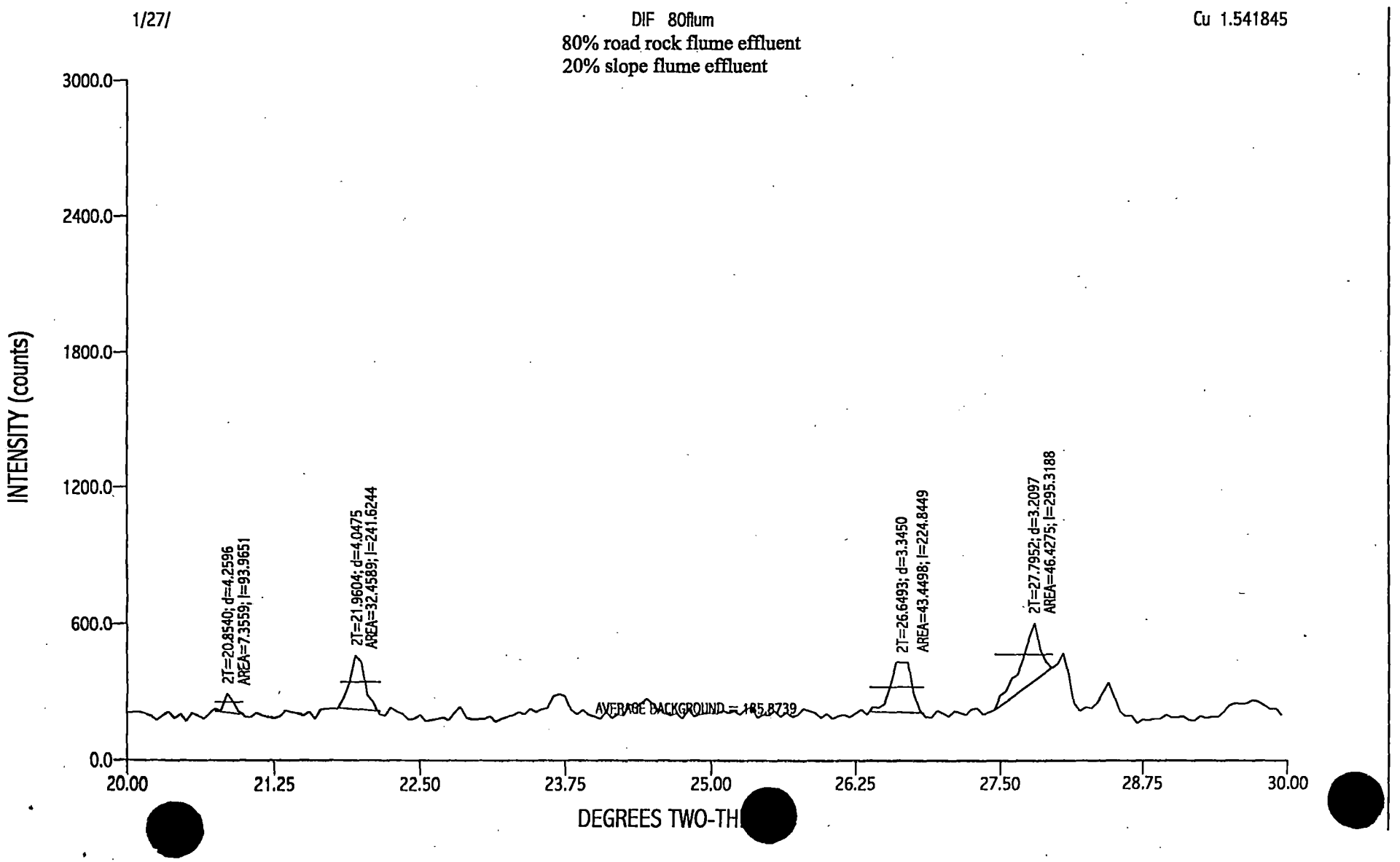

1/14/
DIF 95_134u
95% plot 134 upper road rock
5% plot 134 upper slope
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=22.0400; d=4.0330
AREA=43.6747; I=240.8045
AVERAGE BACKGROUND = 183.2969
2T=26.7028; d=3.3384
AREA=12.3810; I=117.2338
2T=27.8479; d=3.2037
AREA=195.9924; I=976.5654
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

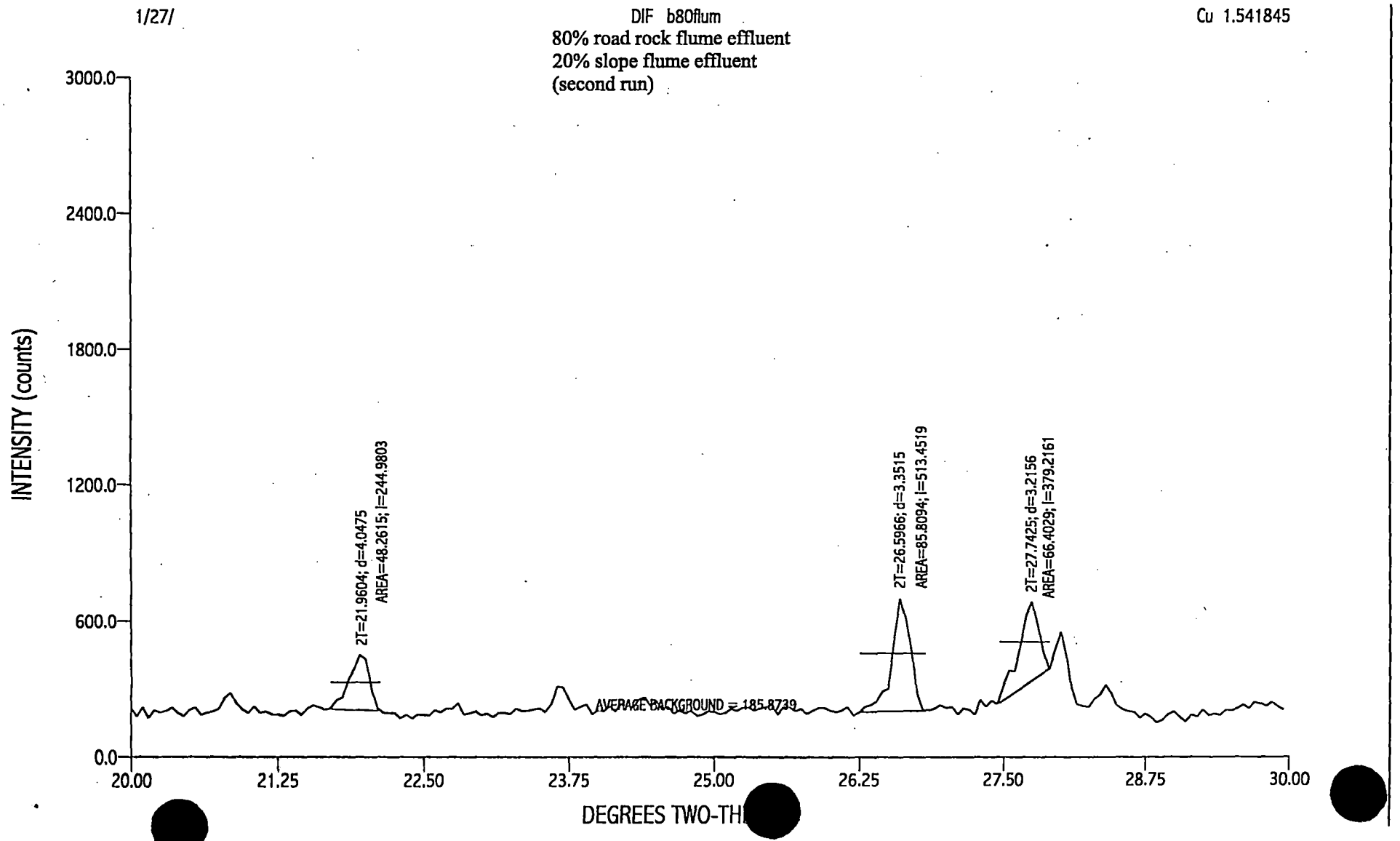

1/14/
DIF b95_134u
95% plot 134 upper road rock
5% plot 134 upper slope
(second run)
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=21.9529; d=4.0488
AREA=46.0236; I=297.8371
AVERAGE BACKGROUND = 183.2969
2T=26.6531; d=3.3446
AREA=15.0417; I=107.7283
2T=27.7952; d=3.2097
AREA=204.2612; I=1238.3252
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

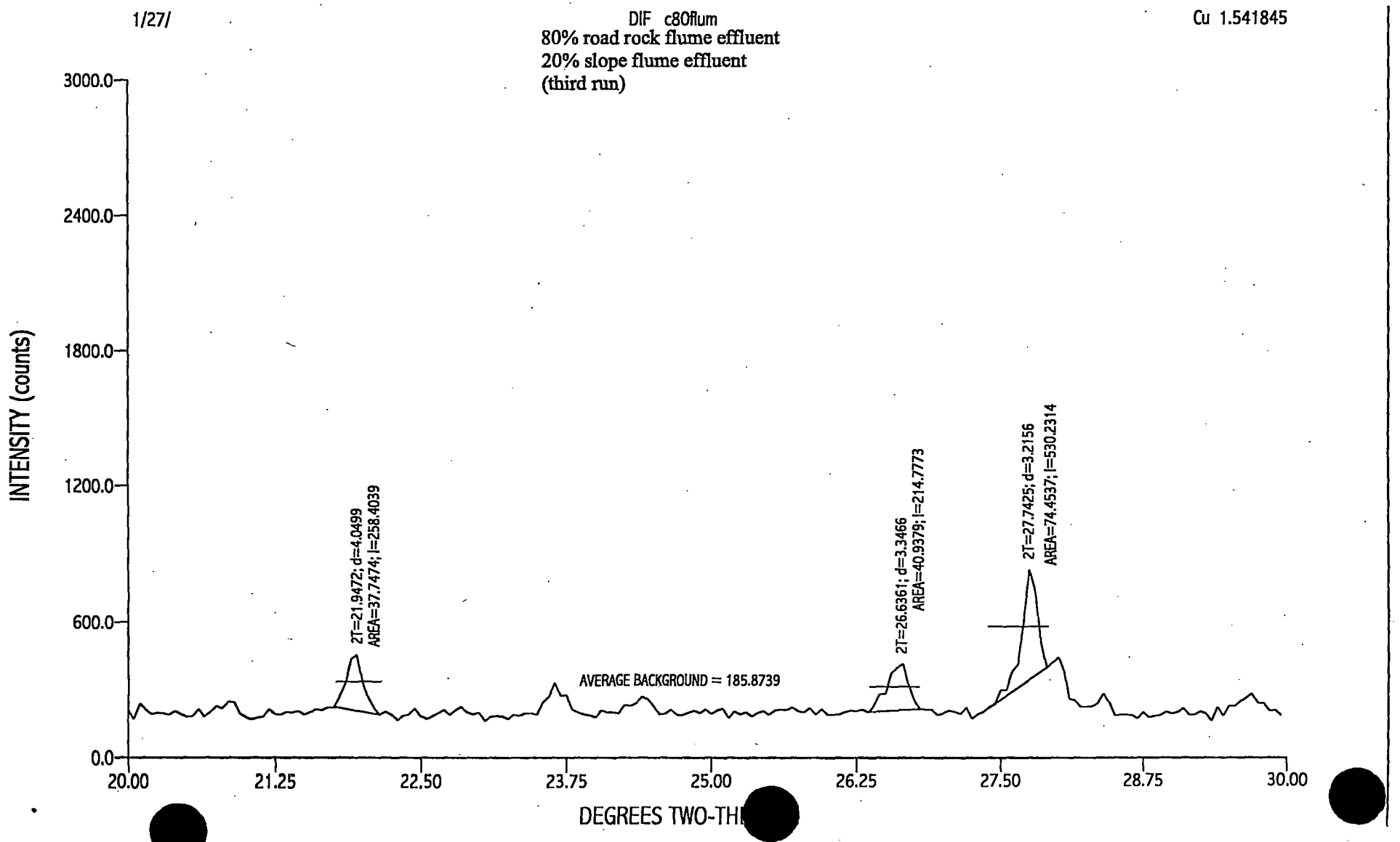

1/14/
DIF c95_134u
95% plot 134 upper road rock
5% plot 134 upper slope
(third run)
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=21.9529; d=4.0488
AREA=58.2613; I=316.8480
AVERAGE BACKGROUND = 170.6230
2T=26.6531; d=3.3446
AREA=19.6260; I=126.7392
2T=27.7952; d=3.2097
AREA=136.5612; I=875.8886
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

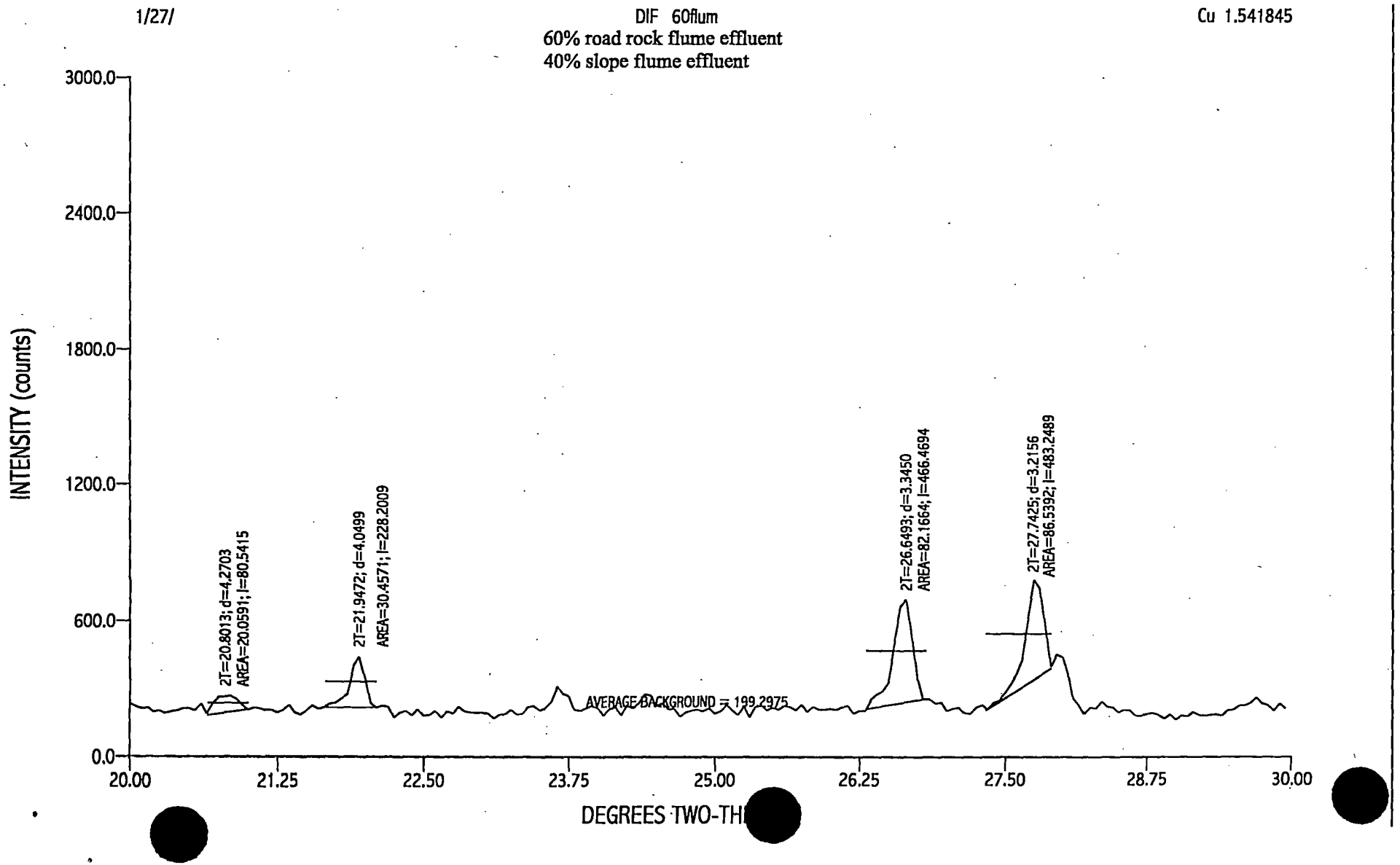
APPENDIX D:

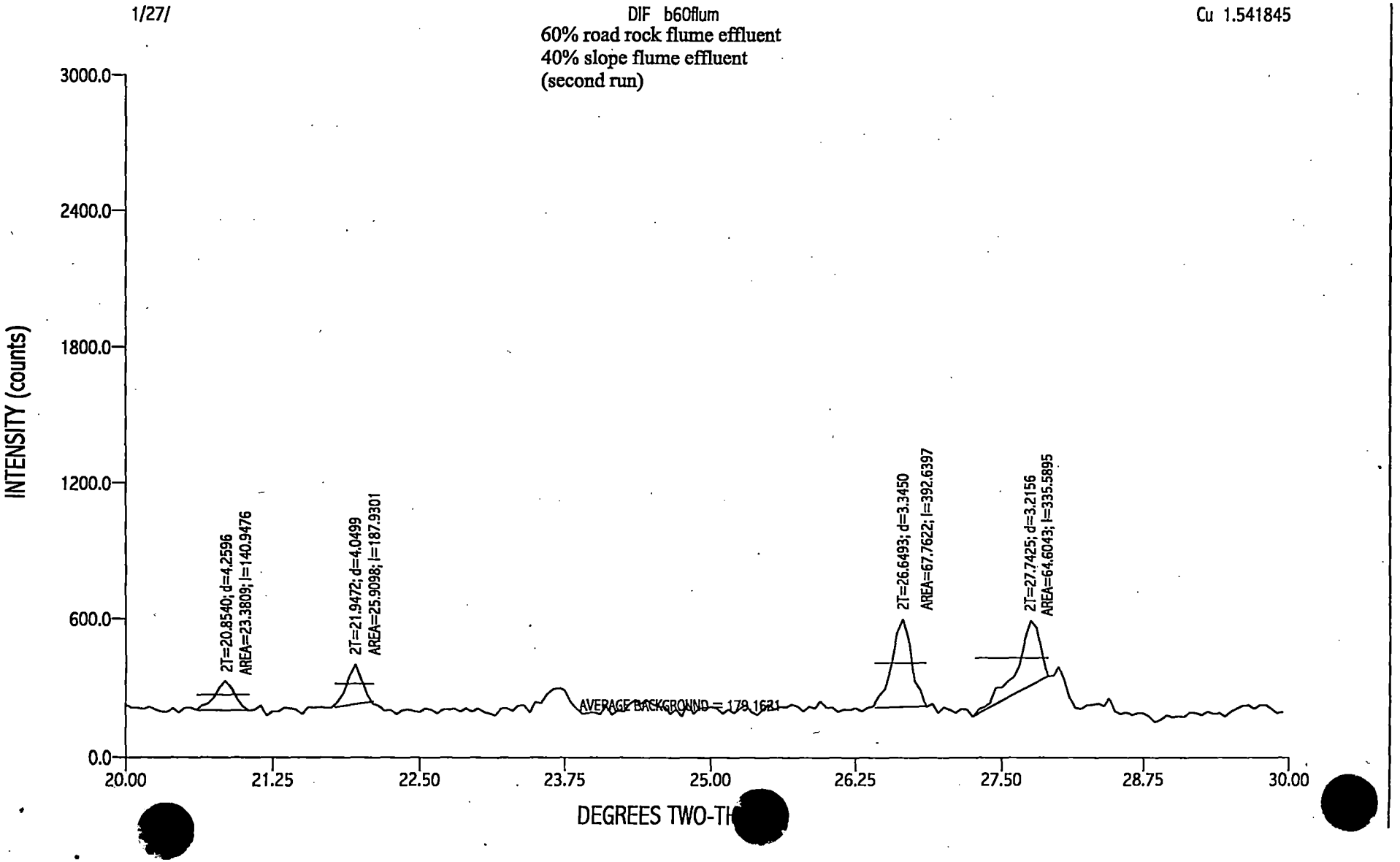
X-ray Diffraction Patterns for Mixtures of Road Rock and Cutslope Material in Known Proportions (Flume Experiments)

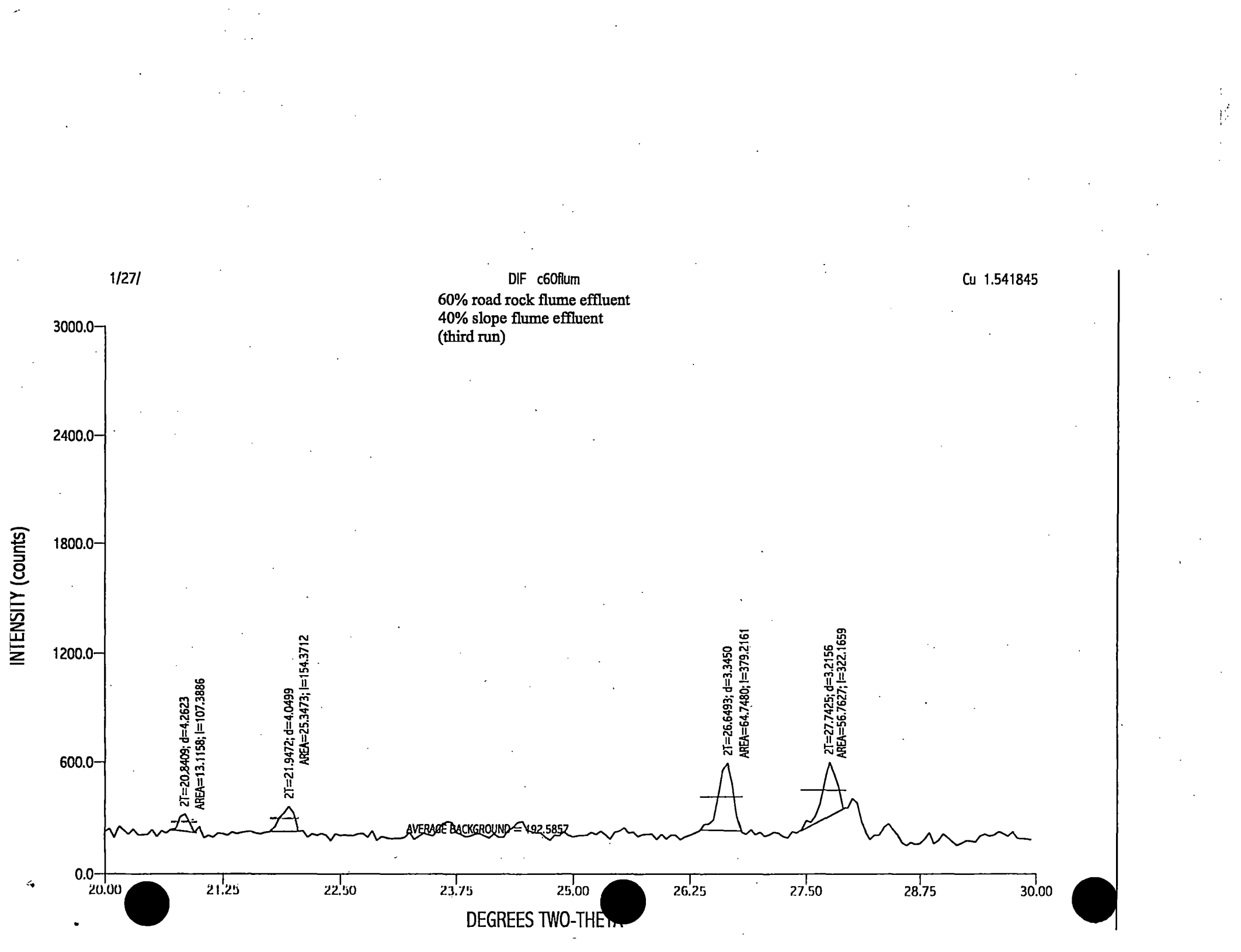

1/27/
DIF 80flum
Cu 1.541845
80% road rock flume effluent
20% slope flume effluent
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=20.8540; d=4.2596
AREA=7.3559; I=93.9651
2T=21.9604; d=4.0475
AREA=32.4589; I=241.6244
AVERAGE BACKGROUND = 185.8739
2T=26.6493; d=3.3450
AREA=43.4498; I=224.8449
2T=27.7952; d=3.2097
AREA=46.4275; I=295.3188
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

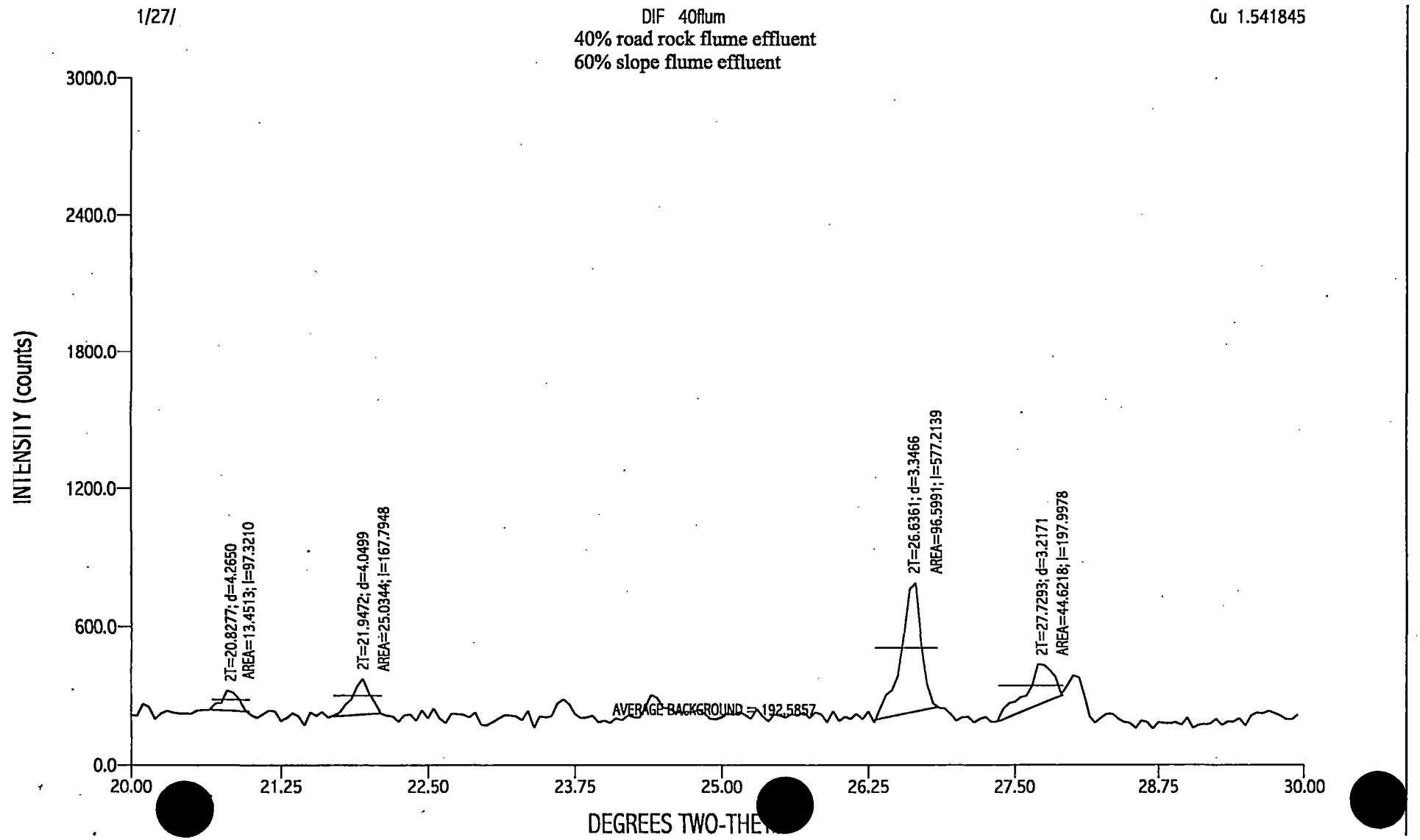

1/27/
DIF b80flum
Cu 1.541845
80% road rock flume effluent
20% slope flume effluent
(second run)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=21.9604; d=4.0475
AREA=48.2615; I=244.9803
2T=26.5966; d=3.3515
AREA=85.8094; I=513.4519
2T=27.7425; d=3.2156
AREA=66.4029; I=379.2161
AVERAGE BACKGROUND = 185.8739
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH


1/27/
DIF c80flum
80% road rock flume effluent
20% slope flume effluent
(third run)
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=21.9472; d=4.0499
AREA=37.7474; I=258.4039
AVERAGE BACKGROUND = 185.8739
2T=26.6361; d=3.3466
AREA=40.9379; I=214.7773
2T=27.7425; d=3.2156
AREA=74.4537; I=530.2314
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH


1/27/
DIF 60flum
60% road rock flume effluent
40% slope flume effluent
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8013; d=4.2703
AREA=20.0591; I=80.5415
2T=21.9472; d=4.0499
AREA=30.4571; I=228.2009
AVERAGE BACKGROUND = 199.2975
2T=26.6493; d=3.3450
AREA=82.1664; I=466.4694
2T=27.7425; d=3.2156
AREA=86.5392; I=483.2489
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH


1/27/
DIF b60flum
Cu 1.541845
60% road rock flume effluent
40% slope flume effluent
(second run)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8540; d=4.2596
AREA=23.3809; I=140.9476
2T=21.9472; d=4.0499
AREA=25.9098; I=187.9301
AVERAGE BACKGROUND = 179.1681
2T=26.6493; d=3.3450
AREA=67.7622; I=392.6397
2T=27.7425; d=3.2156
AREA=64.6043; I=335.5895
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH


1/27/
DIF c60flum
Cu 1.541845
60% road rock flume effluent
40% slope flume effluent
(third run)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8409; d=4.2623
AREA=13.1158; I=107.3886
2T=21.9472; d=4.0499
AREA=25.3473; I=154.3712
AVERAGE BACKGROUND = 192.5857
2T=26.6493; d=3.3450
AREA=64.7480; I=379.2161
2T=27.7425; d=3.2156
AREA=56.7627; I=322.1659
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THETA

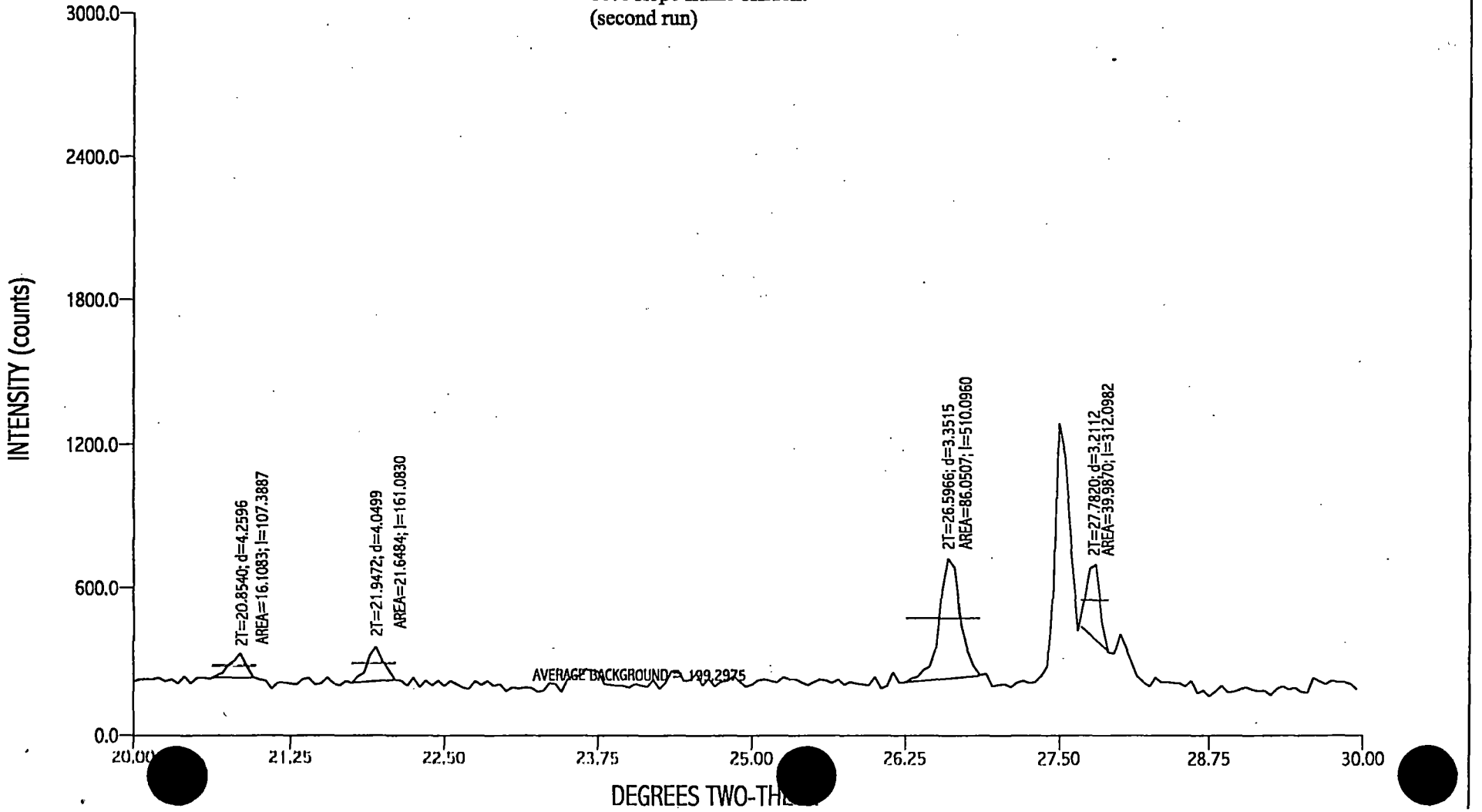

1/27/
DIF 40flum
40% road rock flume effluent
60% slope flume effluent
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8277; d=4.2650
AREA=13.4513; I=97.3210
2T=21.9472; d=4.0499
AREA=25.0344; I=167.7948
2T=26.6361; d=3.3466
AREA=96.5991; I=577.2139
2T=27.7293; d=3.2171
AREA=44.6218; I=197.9978
AVERAGE BACKGROUND = 192.5857
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE

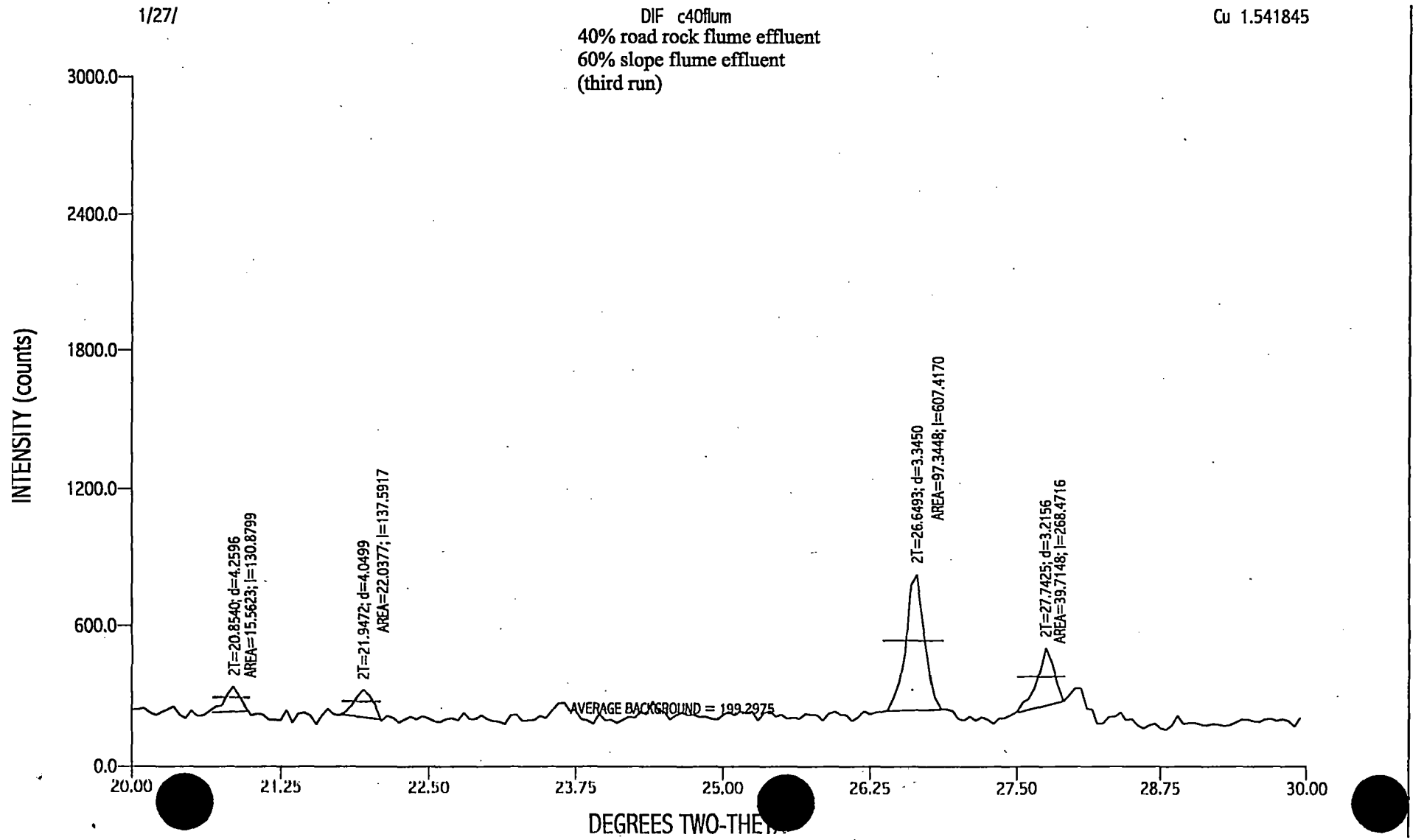
1/27/

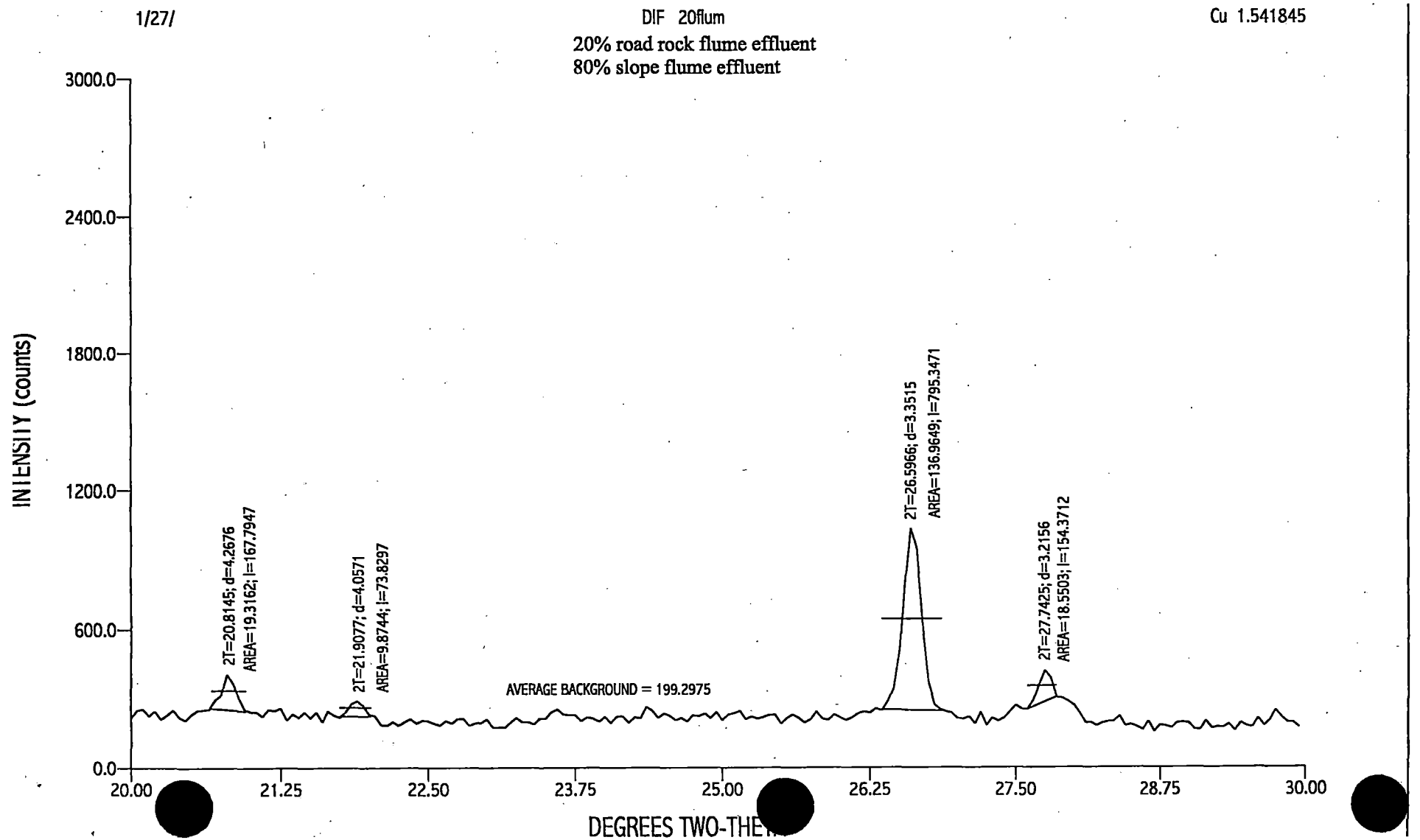
DIF b40flum

40% road rock flume effluent
60% slope flume effluent
(second run)

Cu 1.541845




1/27/
DIF c40flum
40% road rock flume effluent
60% slope flume effluent
(third run)
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8540; d=4.2596
AREA=15.5623; I=130.8799
2T=21.9472; d=4.0499
AREA=22.0377; I=137.5917
2T=26.6493; d=3.3450
AREA=97.3448; I=607.4170
2T=27.7425; d=3.2156
AREA=39.7148; I=268.4716
AVERAGE BACKGROUND = 199.2975
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE

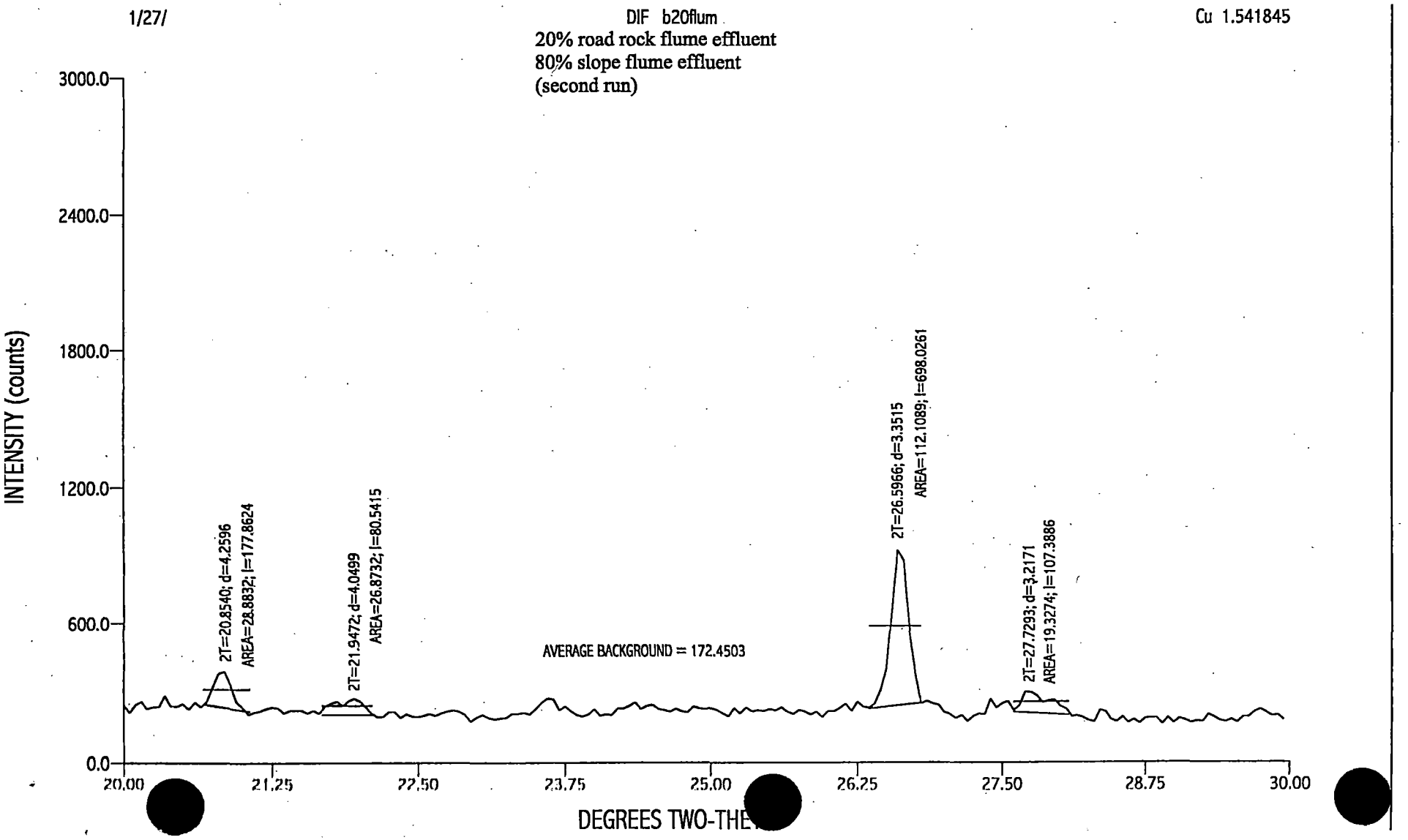

1/27/
DIF 20flum
Cu 1.541845
20% road rock flume effluent
80% slope flume effluent
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=20.8145; d=4.2676
AREA=19.3162; I=167.7947
2T=21.9077; d=4.0571
AREA=9.8744; I=73.8297
AVERAGE BACKGROUND = 199.2975
2T=26.5966; d=3.3515
AREA=136.9649; I=795.3471
2T=27.7425; d=3.2156
AREA=18.5503; I=154.3712
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE

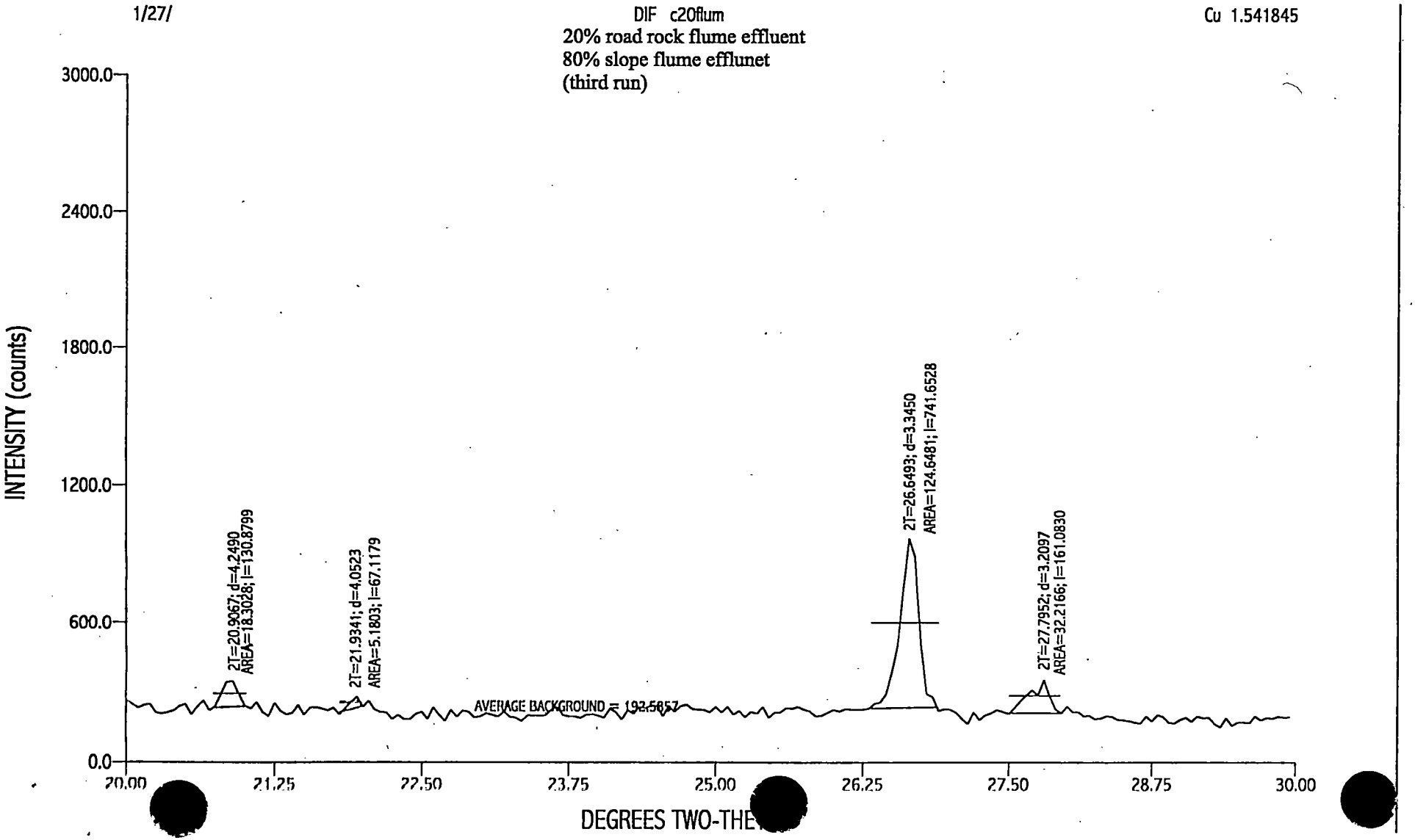
1/27/

DIF b20flum

20% road rock flume effluent
80% slope flume effluent
(second run)

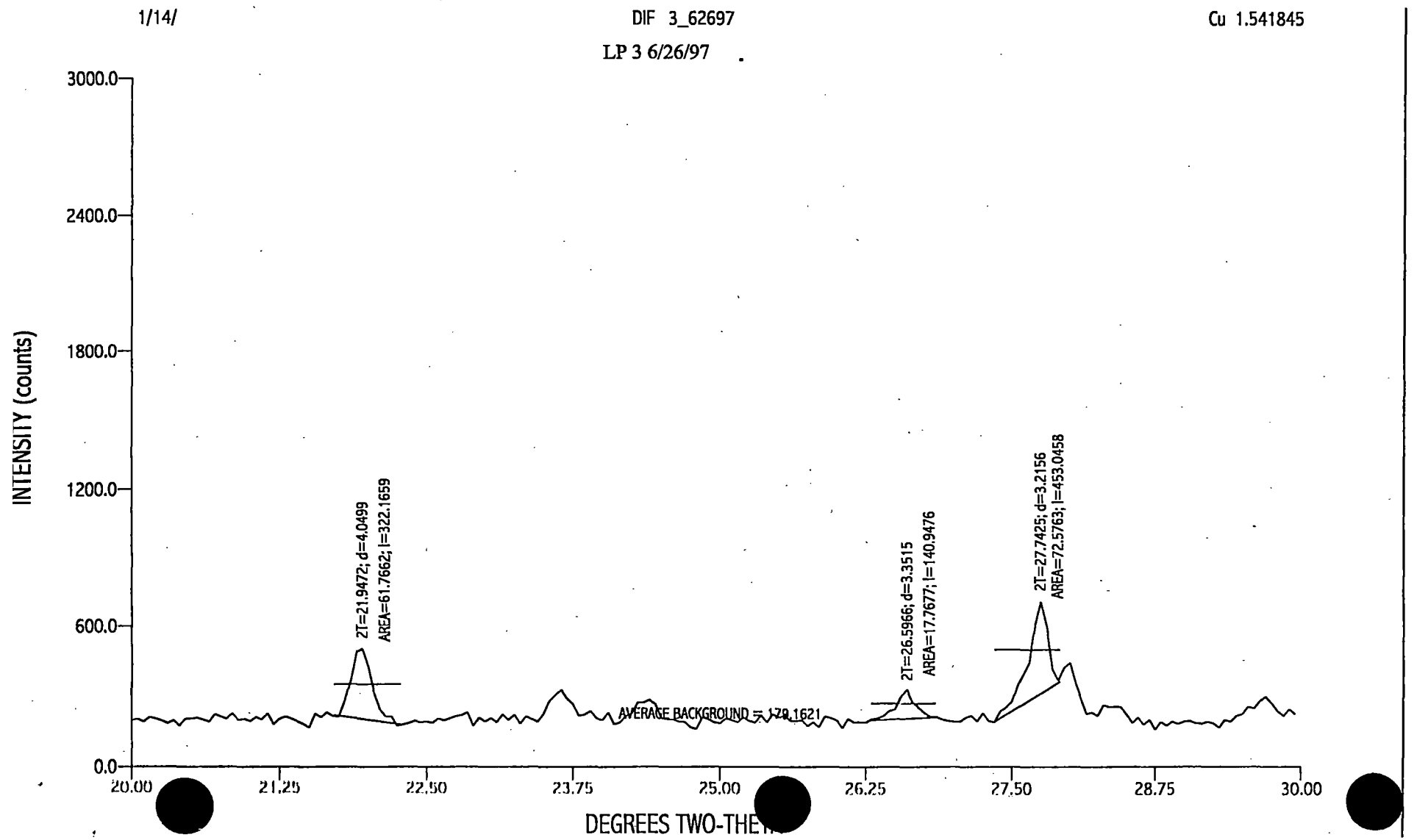
Cu 1.541845




1/27/
DIF c20flum
20% road rock flume effluent
80% slope flume efflunet
(third run)
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.9067; d=4.2490
AREA=18.3028; I=130.8799
2T=21.9341; d=4.0523
AREA=5.1803; I=67.1179
2T=26.6493; d=3.3450
AREA=124.6481; I=741.6528
2T=27.7952; d=3.2097
AREA=32.2166; I=161.0830
AVERAGE BACKGROUND = 192.5857
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE

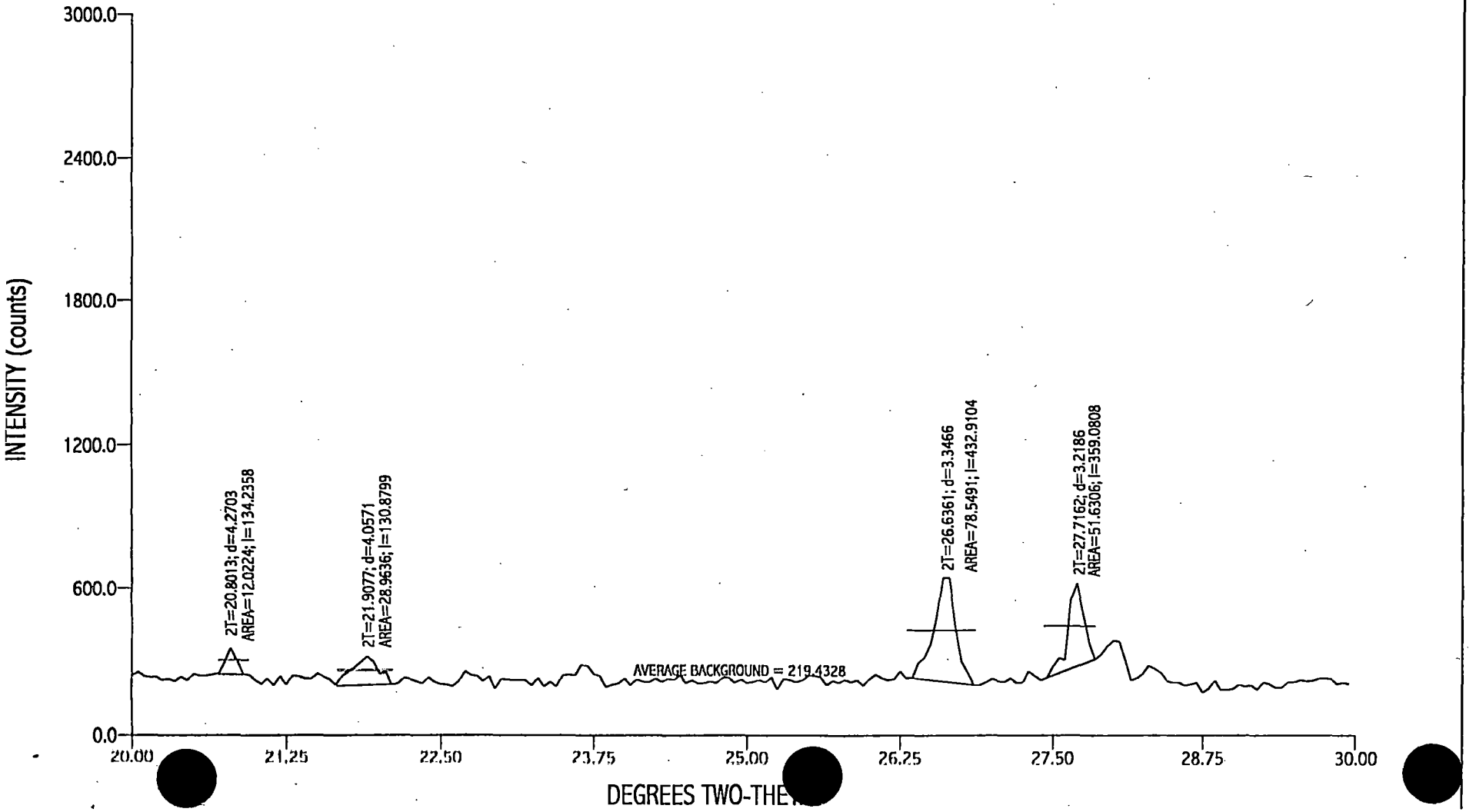
APPENDIX E:

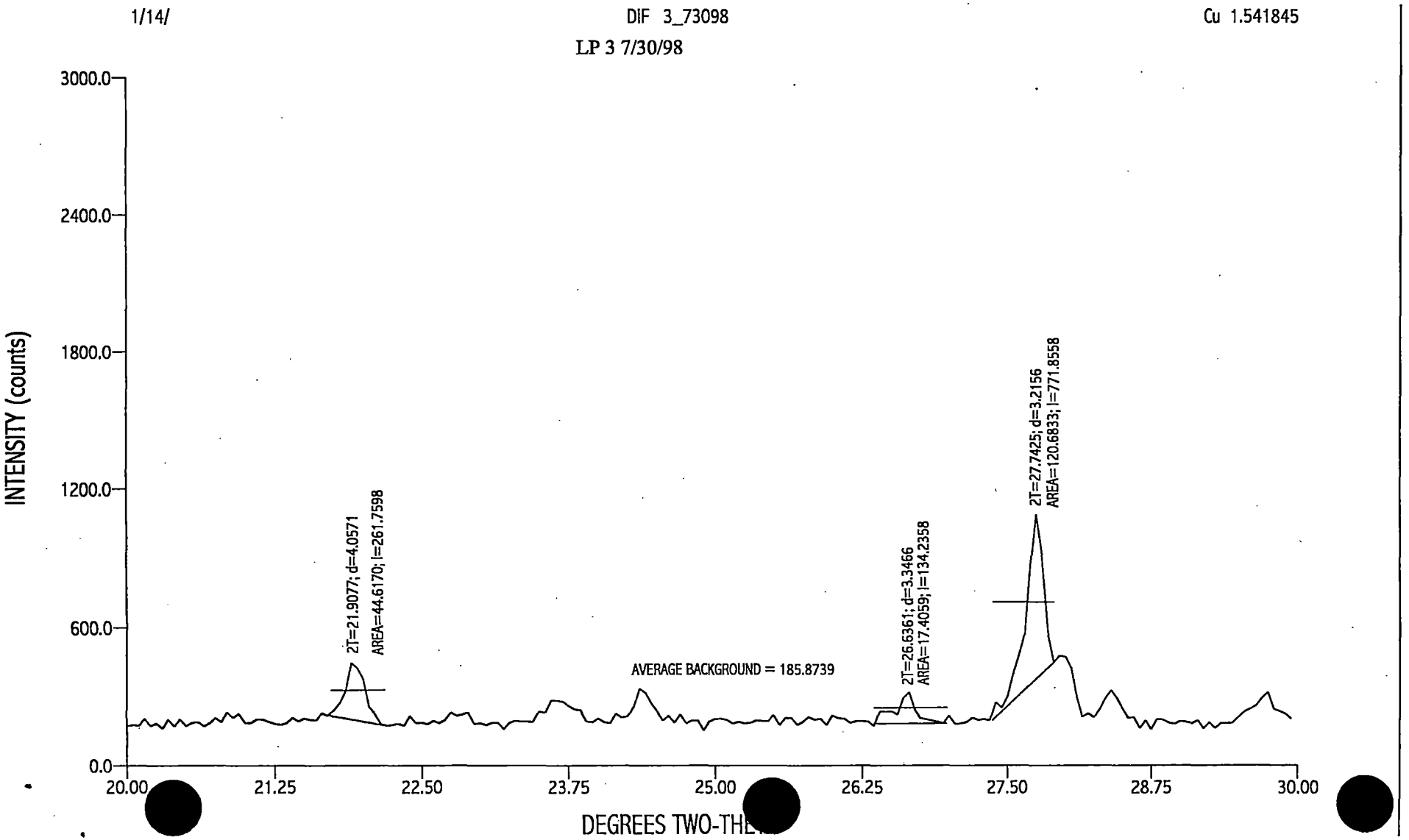
X-ray Diffraction Patterns for Samples of Unknown Composition


1/14/
DIF 3_62697
LP 3 6/26/97
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=21.9472; d=4.0499
AREA=61.7662; I=322.1659
2T=26.5966; d=3.3515
AREA=17.7677; I=140.9476
2T=27.7425; d=3.2156
AREA=72.5763; I=453.0458
AVERAGE BACKGROUND = 179.1621
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE

1/14/ DIF 3_72897 Cu 1.541845

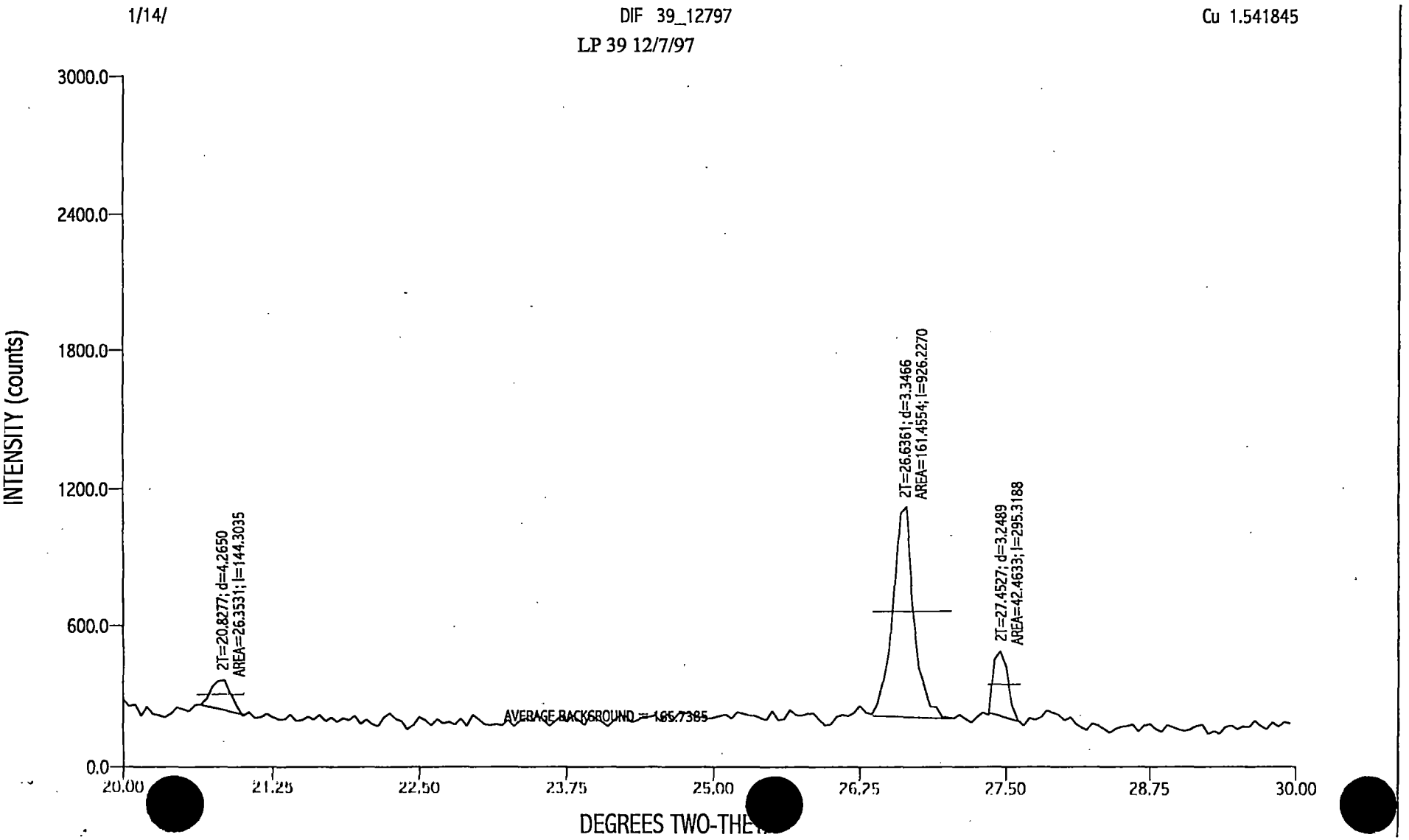
LP 3 7/28/97

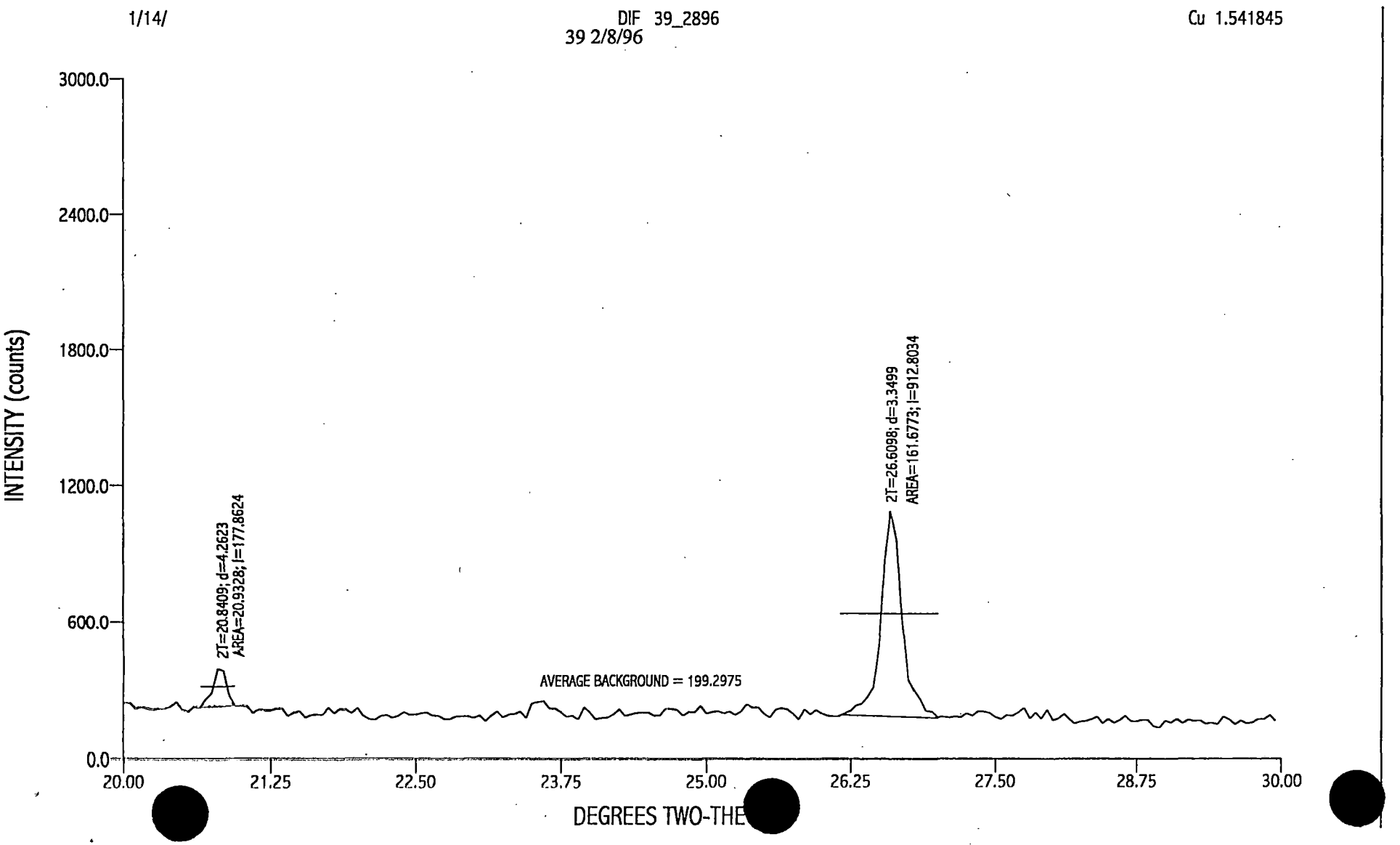


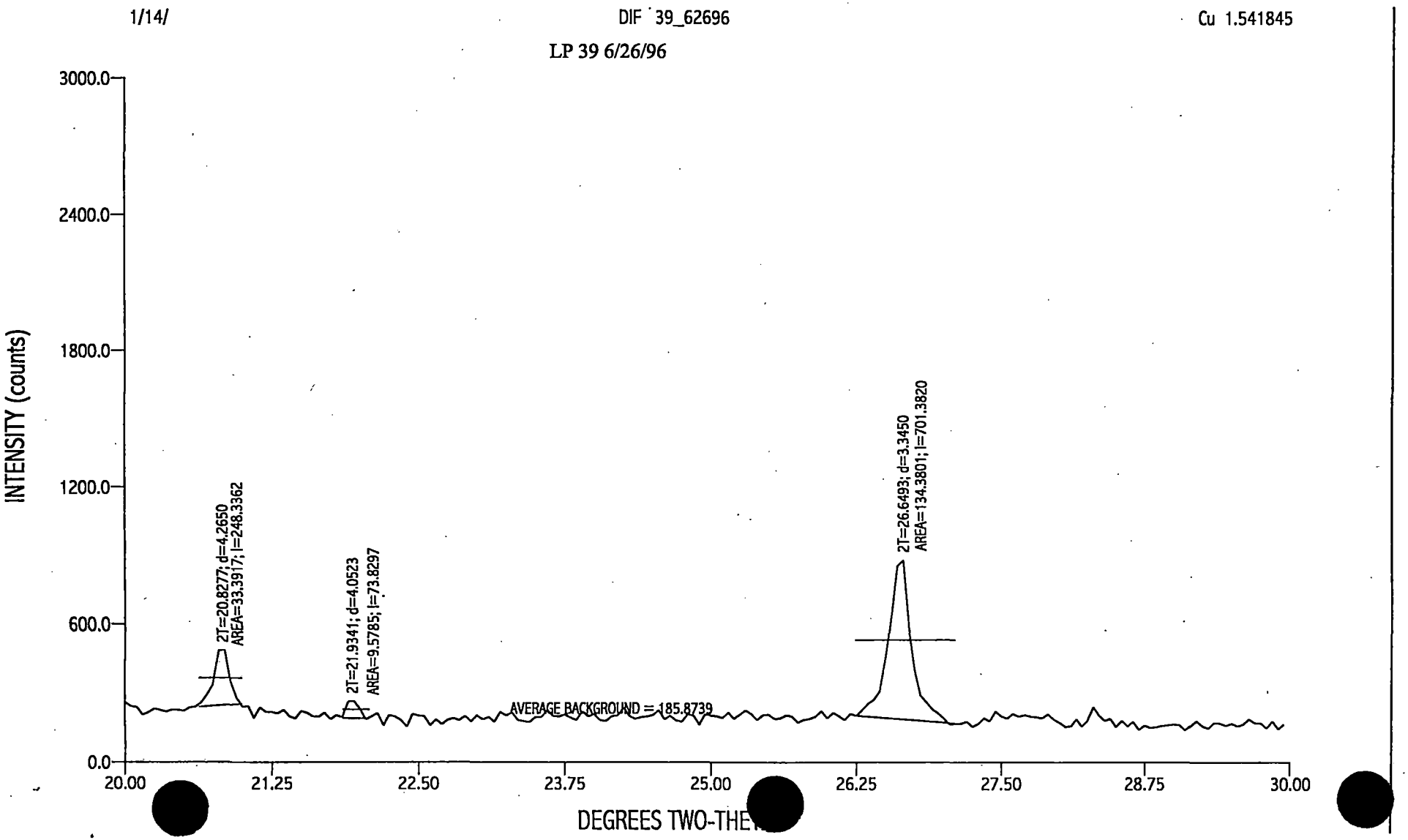

1/14/
DIF 3_73098
Cu 1.541845
LP 3 7/30/98
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=21.9077; d=4.0571
AREA=44.6170; I=261.7598
AVERAGE BACKGROUND = 185.8739
2T=26.6361; d=3.3466
AREA=17.4059; I=134.2358
2T=27.7425; d=3.2156
AREA=120.6833; I=771.8558
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE

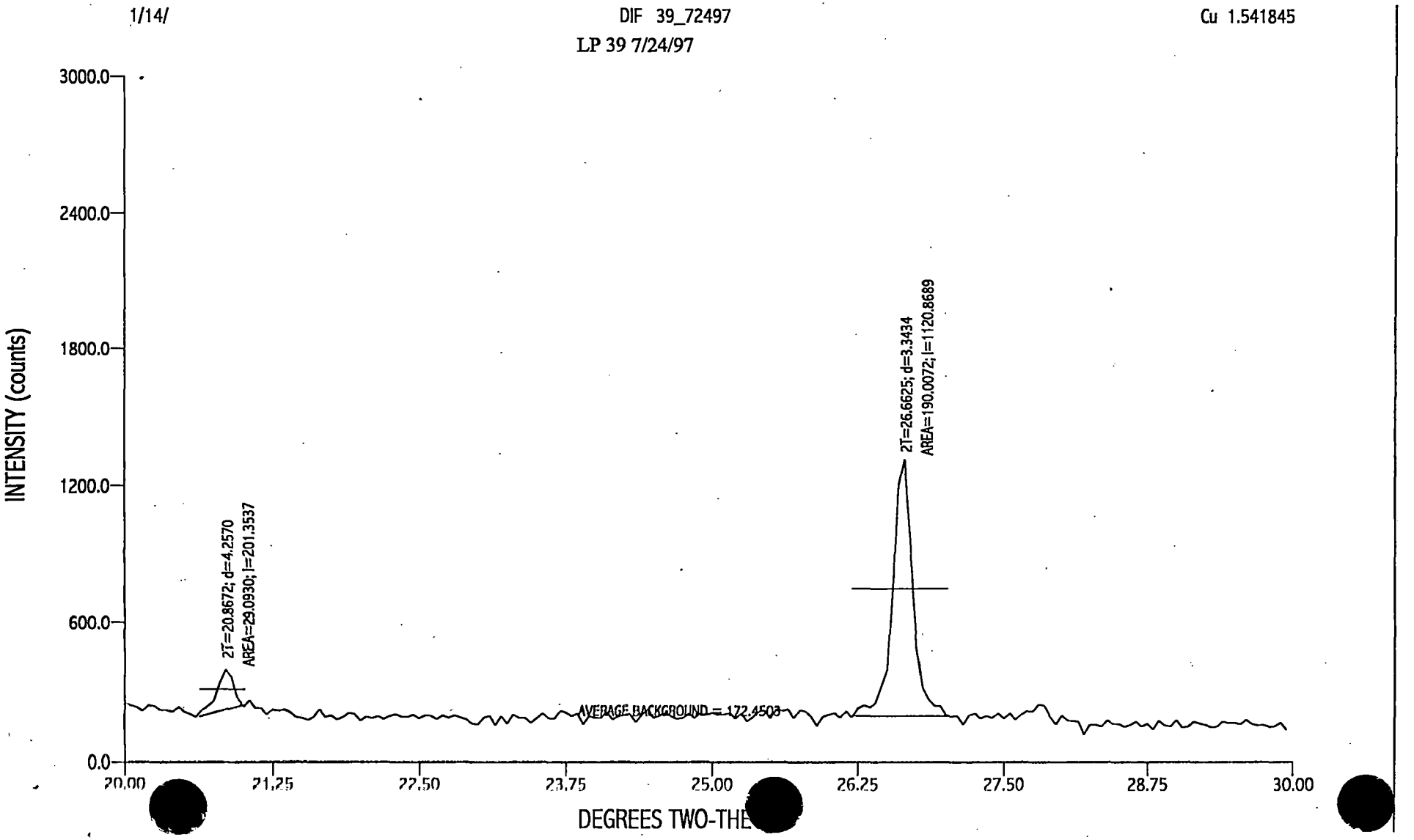
1/14/ DIF 39_12797 Cu 1.541845

LP 39 12/7/97




1/14/
DIF 39_2896
39 2/8/96
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8409; d=4.2623
AREA=20.9328; I=177.8624
2T=26.6098; d=3.3499
AREA=161.6773; I=912.8034
AVERAGE BACKGROUND = 199.2975
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE

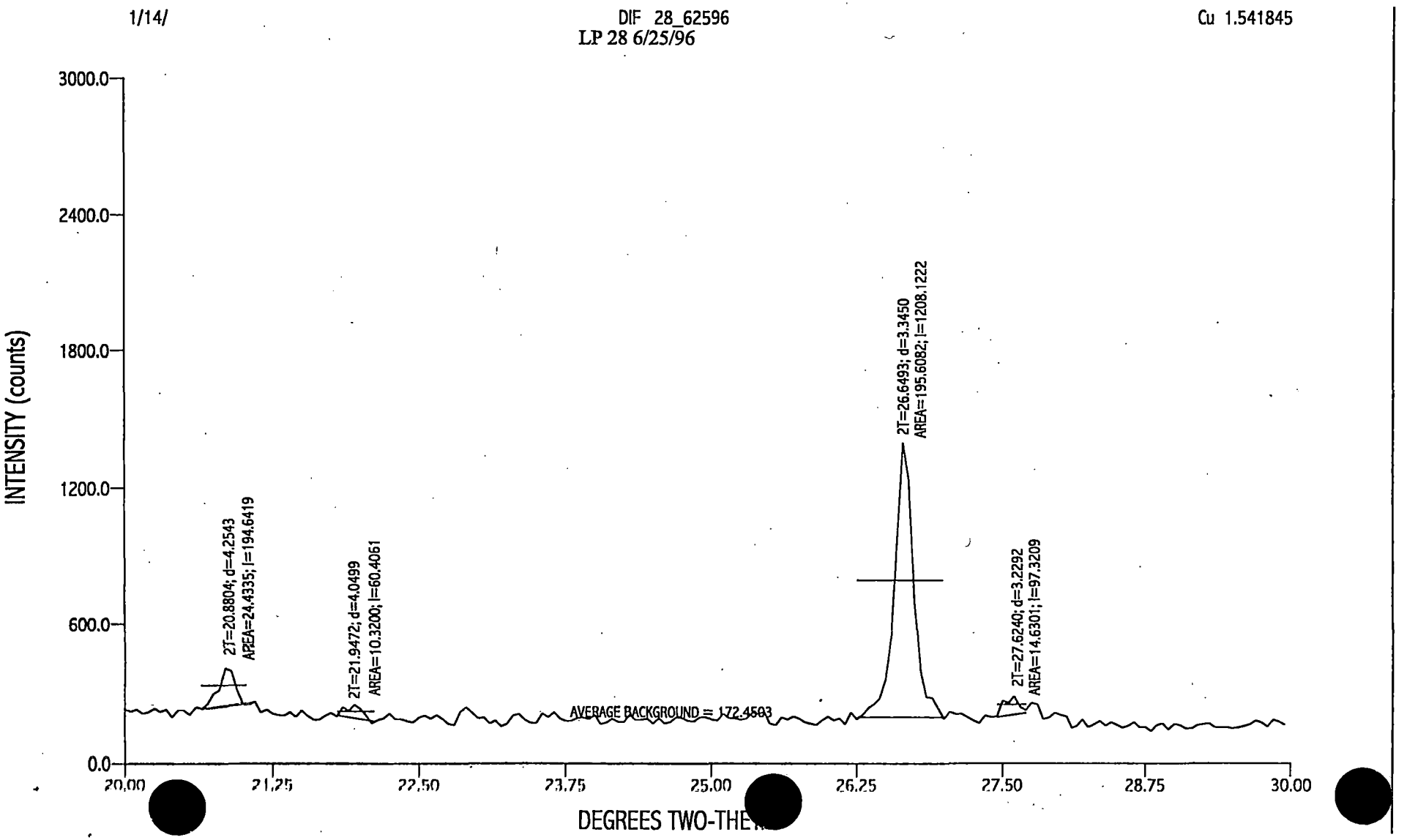

1/14/
DIF 39_62696
Cu 1.541845
LP 39 6/26/96
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8277; d=4.2650
AREA=33.3917; I=248.3362
2T=21.9341; d=4.0523
AREA=9.5785; I=73.8297
2T=26.6493; d=3.3450
AREA=134.3801; I=701.3820
AVERAGE BACKGROUND = 185.8739
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE


1/14/
DIF 39_72497
Cu 1.541845
LP 39 7/24/97
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8672; d=4.2570
AREA=29.0930; I=201.3537
2T=26.6625; d=3.3434
AREA=190.0072; I=1120.8689
AVERAGE BACKGROUND = 172.4503
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE

1/14/

DIF 28_62596
LP 28 6/25/96

Cu 1.541845

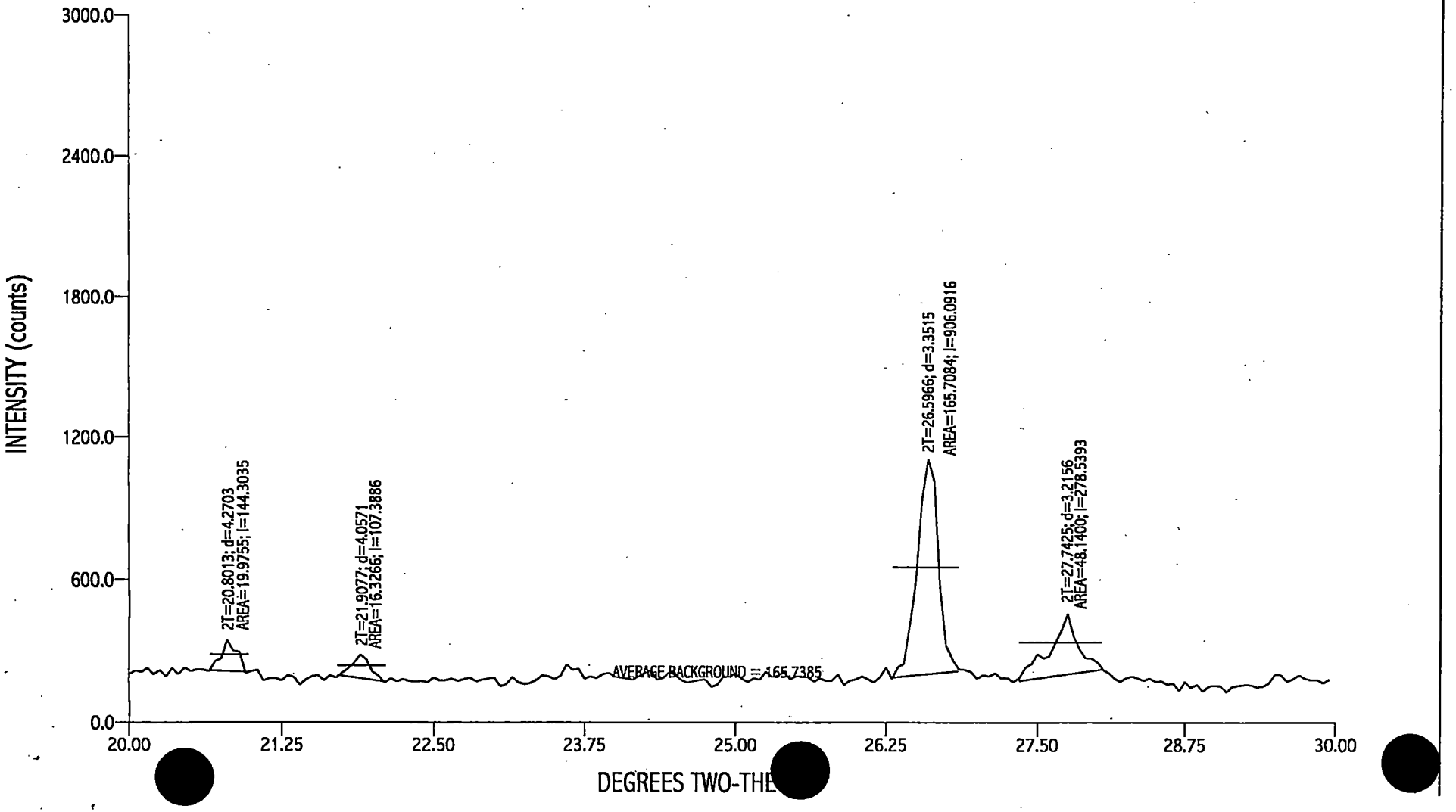


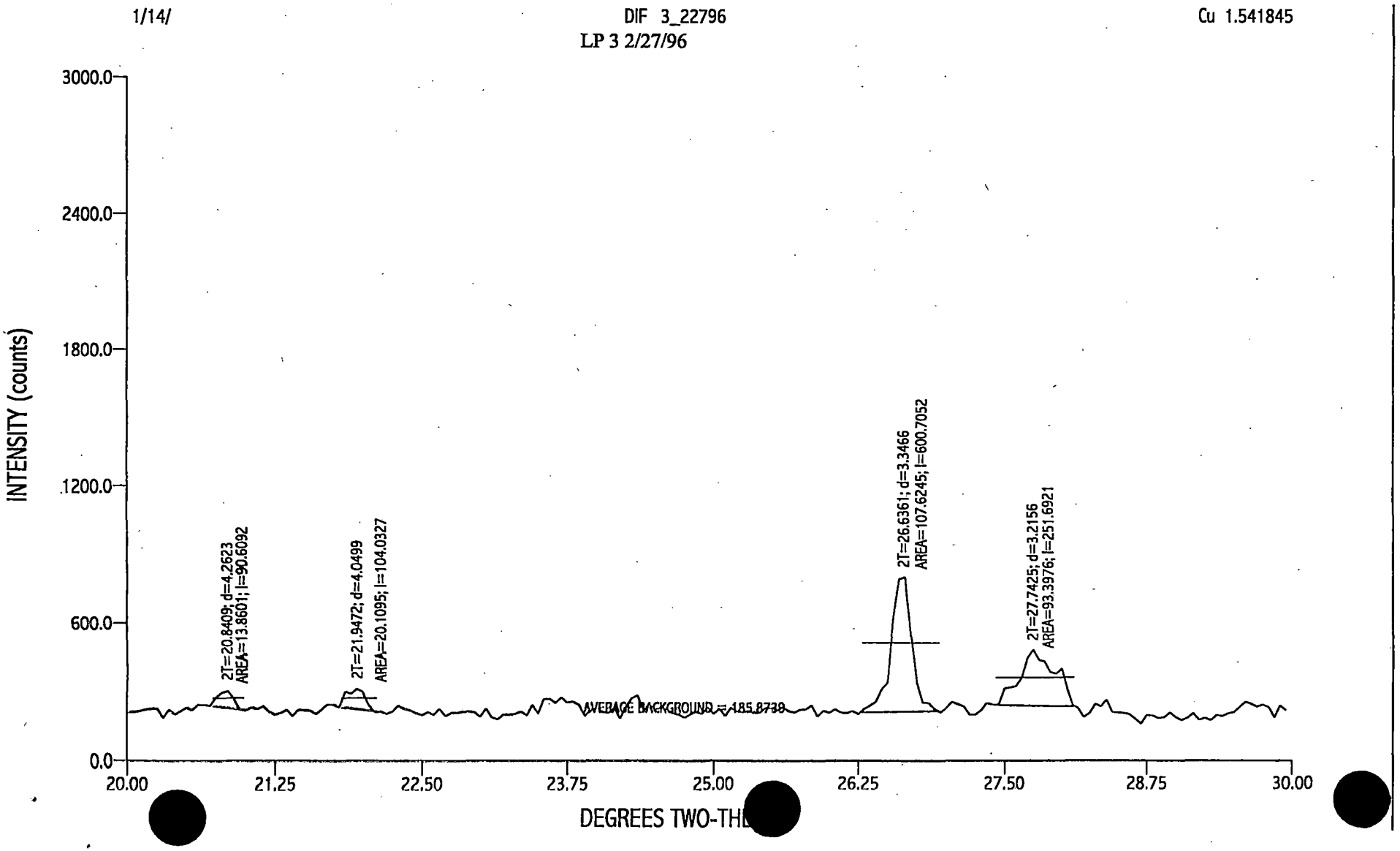
1/14/

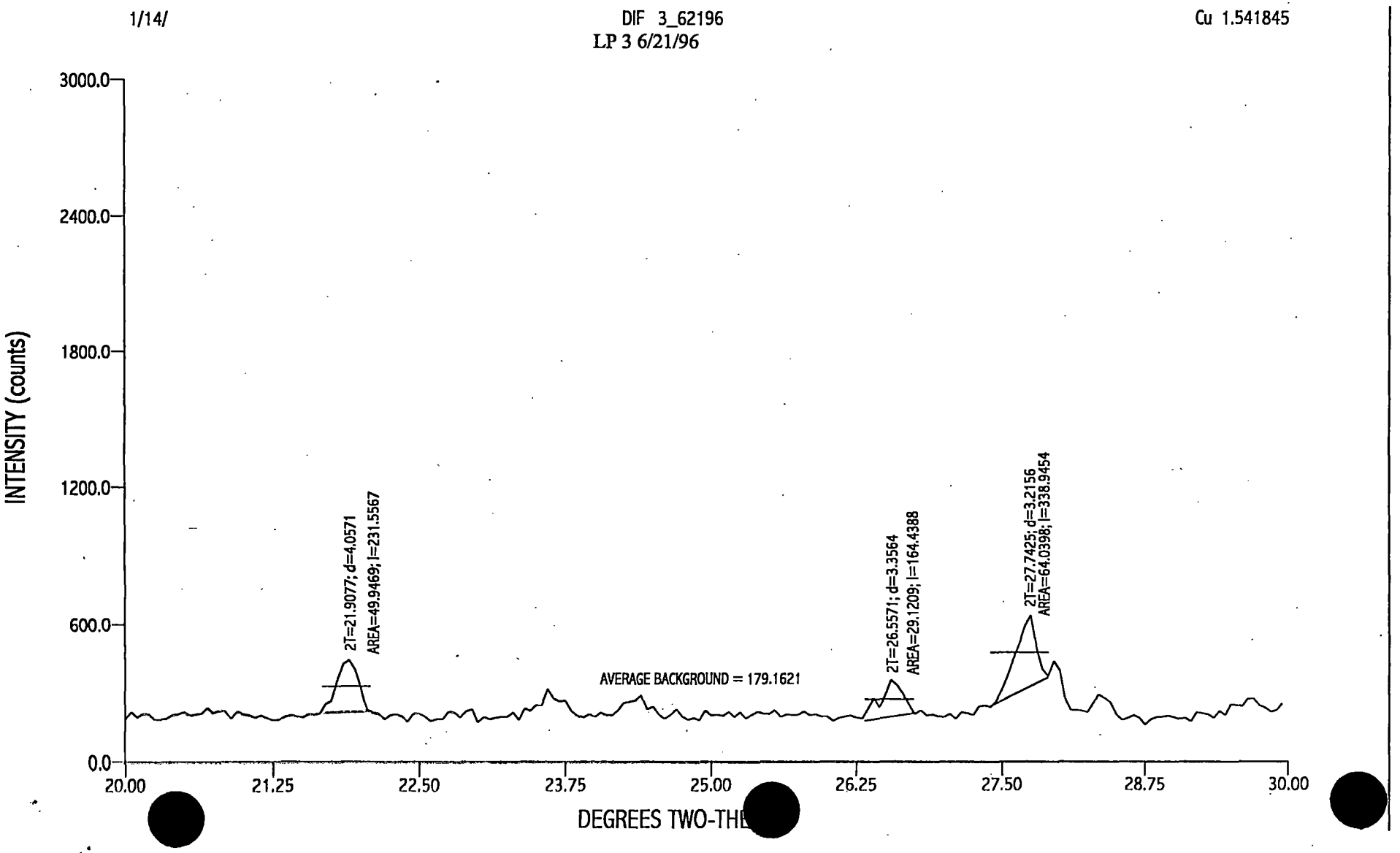
DIF 28_72297

LP 28 7/22/97

Cu 1.541845

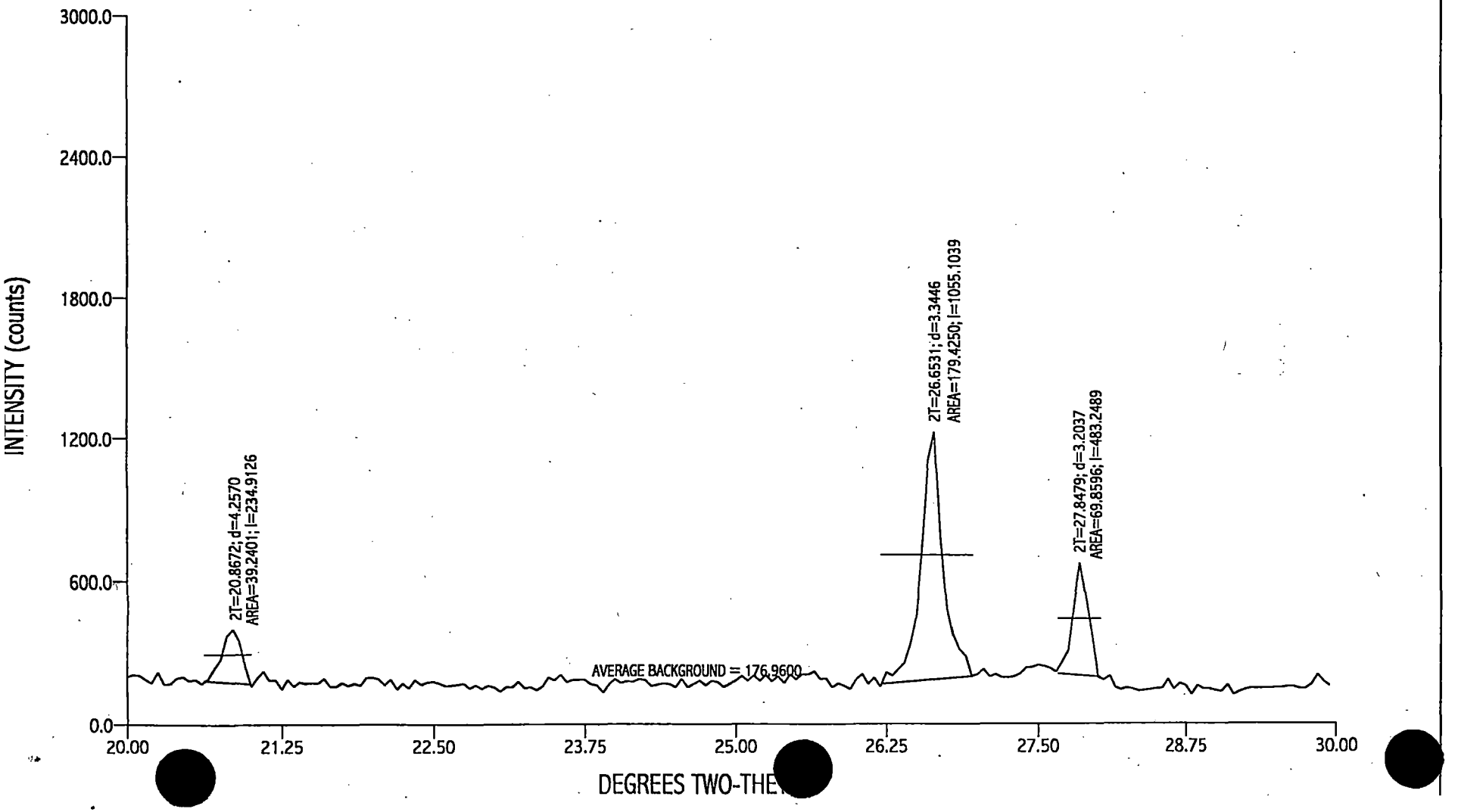



1/14/
DIF 3_22796
LP 3 2/27/96
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8409; d=4.2623
AREA=13.8601; I=90.6092
2T=21.9472; d=4.0499
AREA=20.1095; I=104.0327
2T=26.6361; d=3.3466
AREA=107.6245; I=600.7052
2T=27.7425; d=3.2156
AREA=93.3976; I=251.6921
AVERAGE BACKGROUND = 185.8738
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH


1/14/
DIF 3_62196
LP 3 6/21/96
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=21.9077; d=4.0571
AREA=49.9469; I=231.5567
AVERAGE BACKGROUND = 179.1621
2T=26.5571; d=3.3564
AREA=29.1209; I=164.4388
2T=27.7425; d=3.2156
AREA=64.0398; I=338.9454
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE

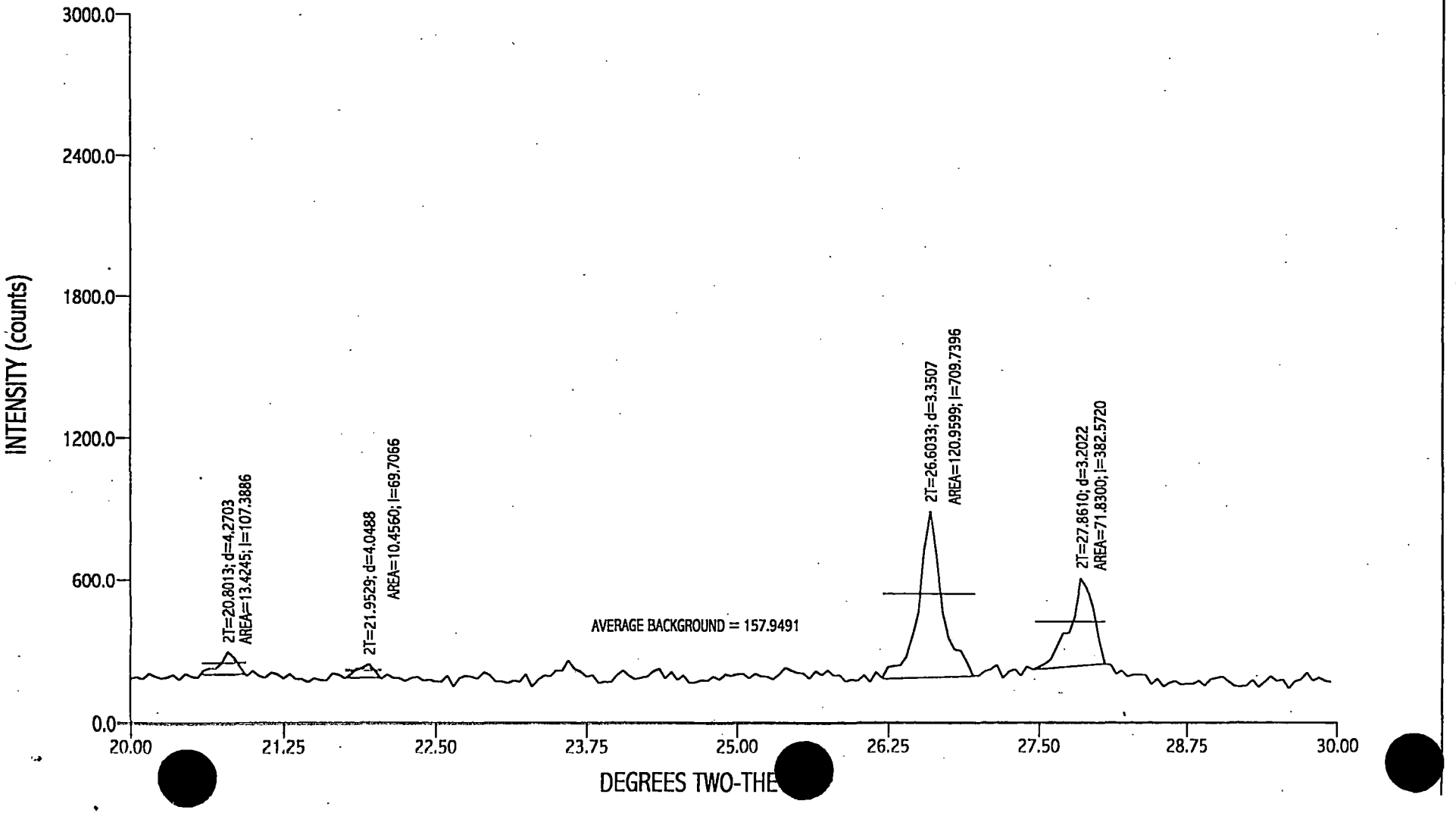
1/14/ DIF 17_22196 Cu 1.541845

LP 17 2/21/96



1/14/ DIF 17_7897 Cu 1.541845

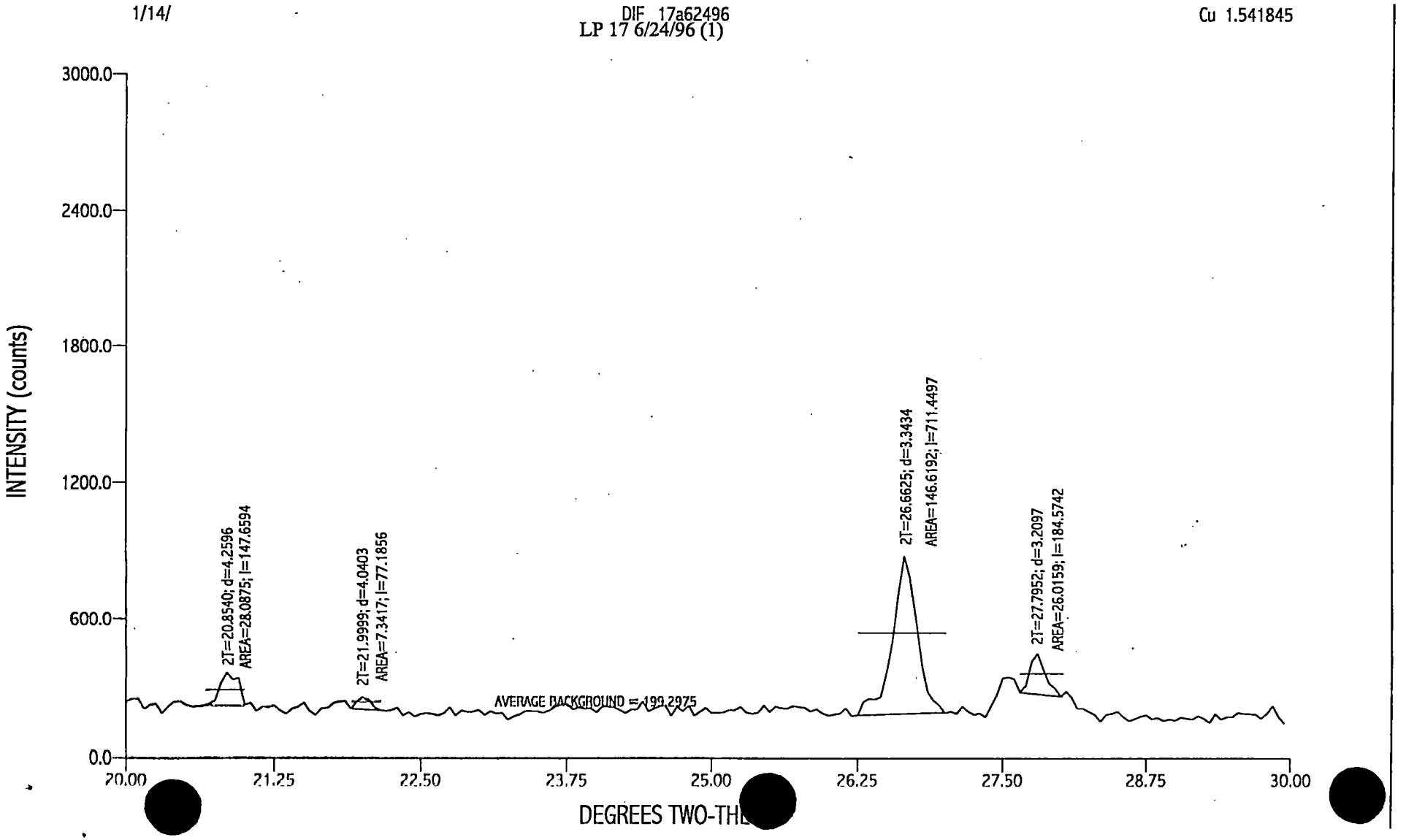
LP 17 7/8/97

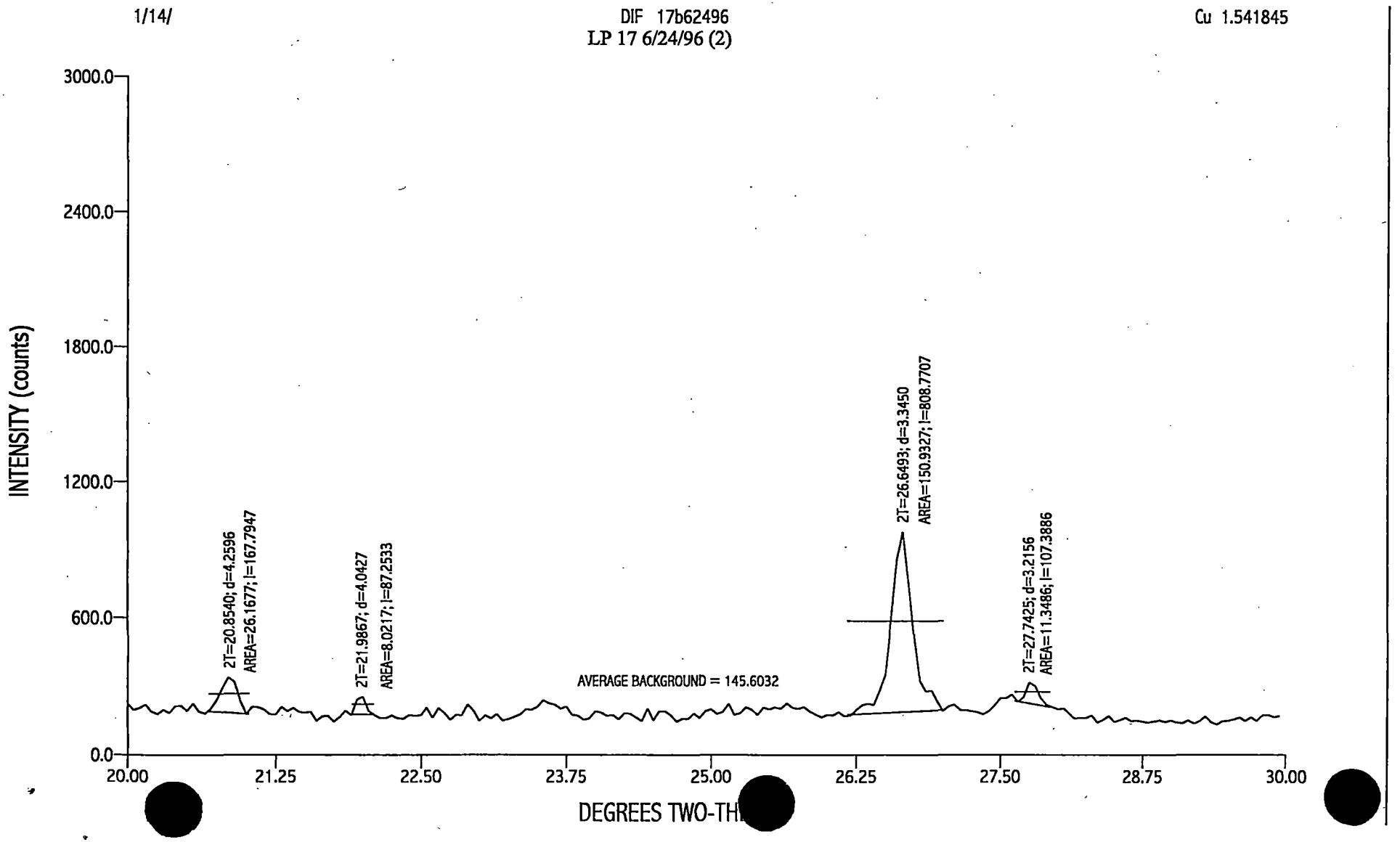


1/14/

DIF 17a62496
LP 17 6/24/96 (1)

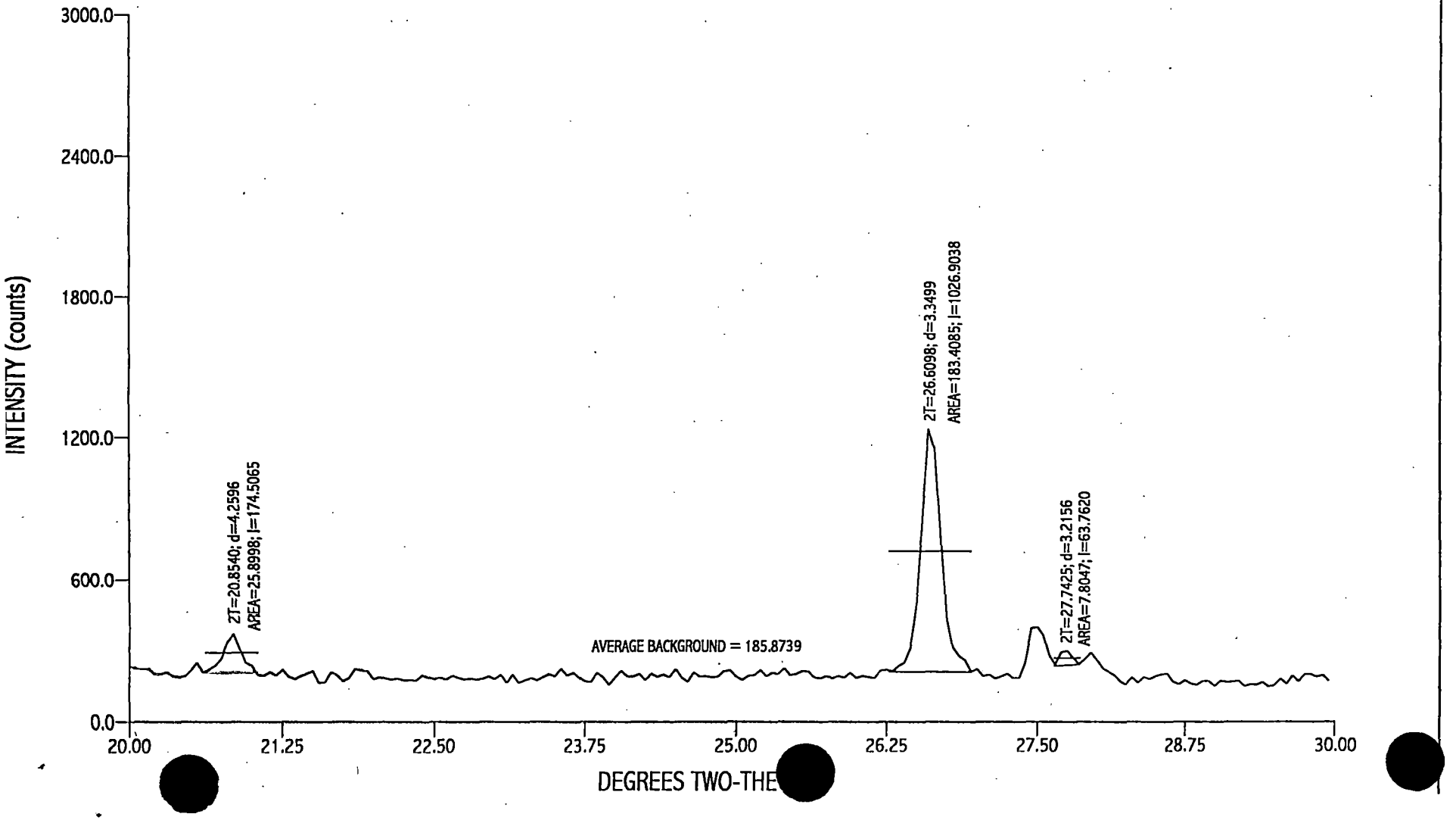
Cu 1.541845

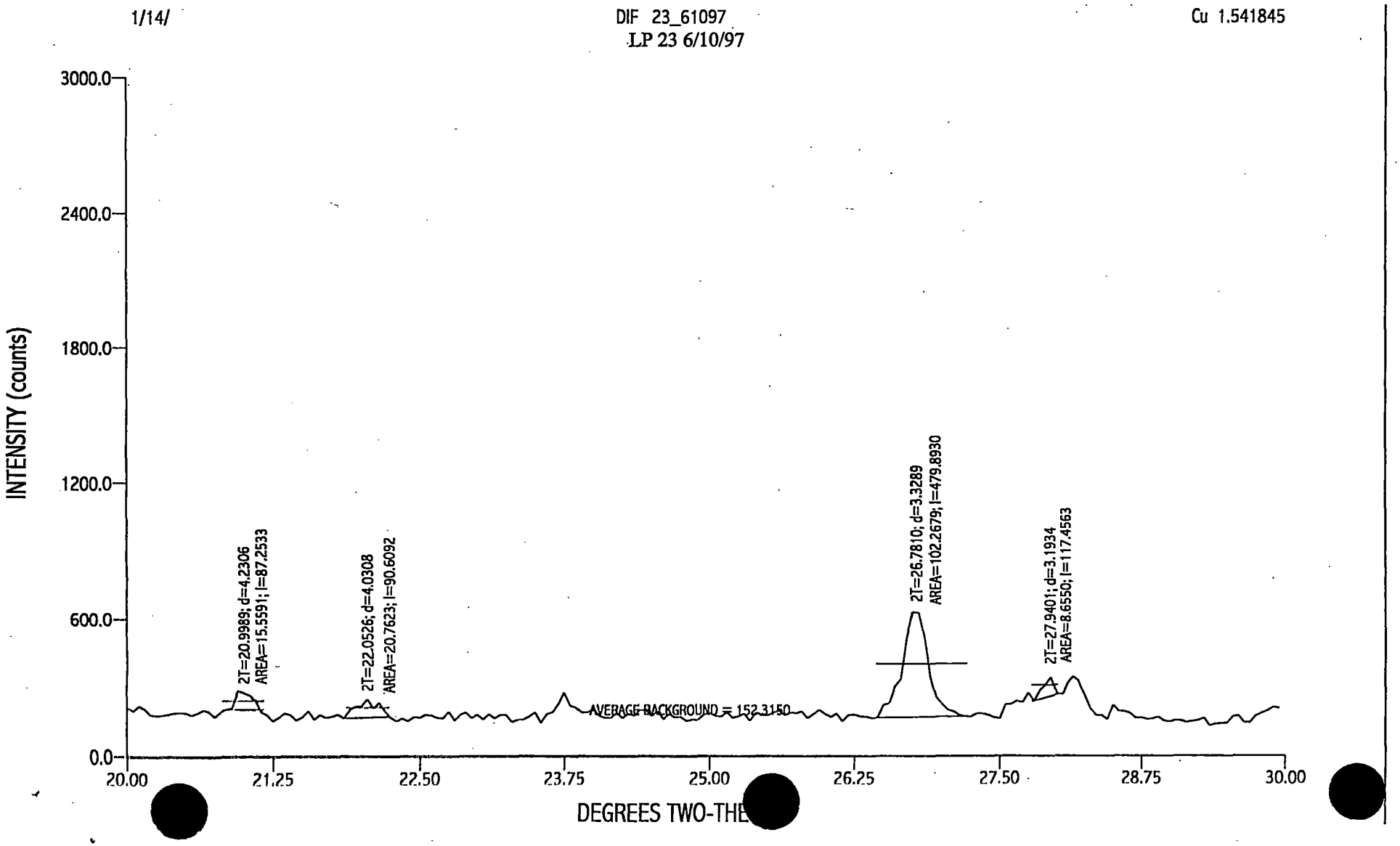


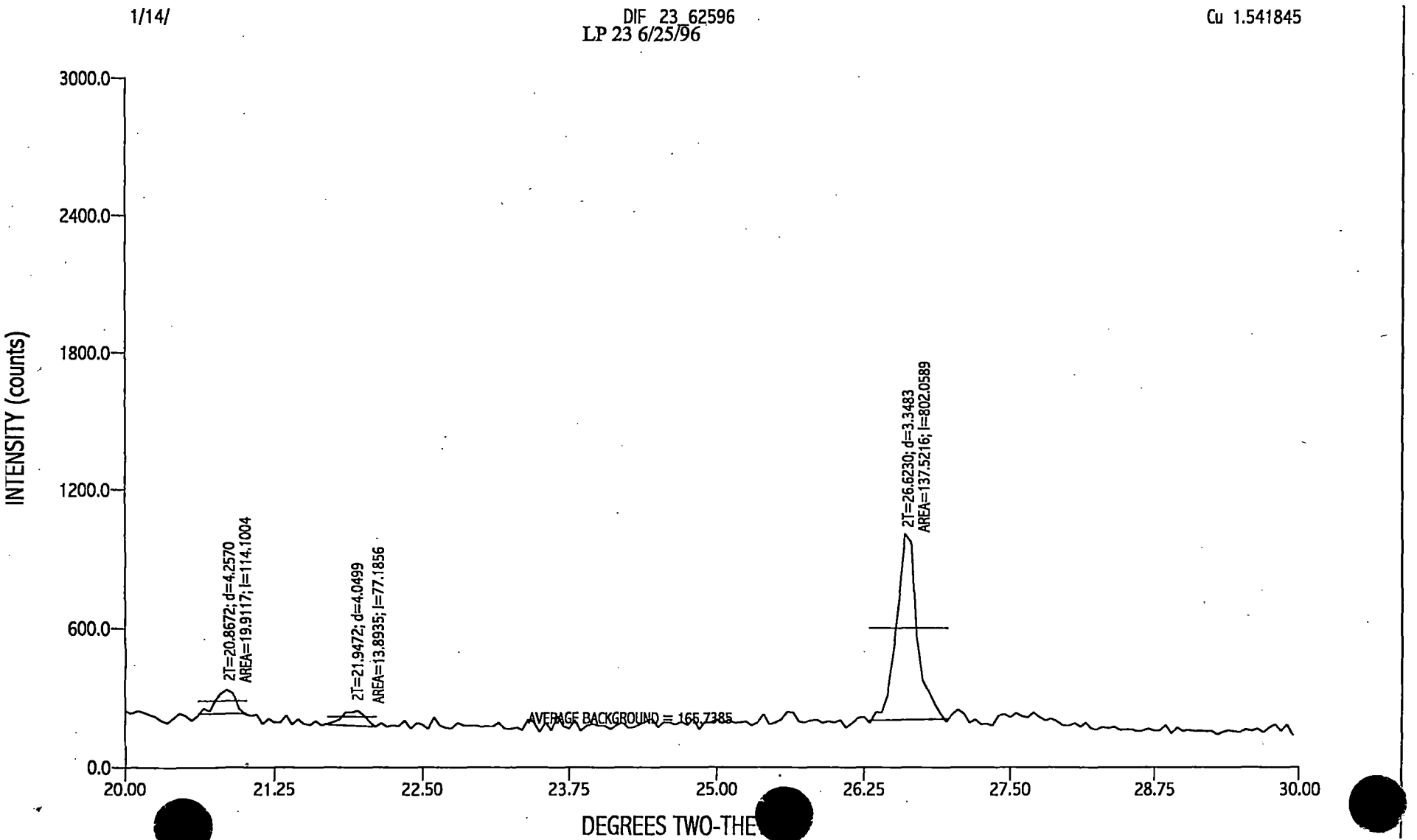

1/14/
DIF 17b62496
LP 17 6/24/96 (2)
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=20.8540; d=4.2596
AREA=26.1677; I=167.7947
2T=21.9867; d=4.0427
AREA=8.0217; I=87.2533
AVERAGE BACKGROUND = 145.6032
2T=26.6493; d=3.3450
AREA=150.9327; I=808.7707
2T=27.7425; d=3.2156
AREA=11.3486; I=107.3886
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-TH

1/14/ DIF 23_21596 Cu 1.541845

23 Box grab 2/15/96




1/14/
DIF 23_61097
LP 23 6/10/97
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=20.9989; d=4.2306
AREA=15.5591; I=87.2533
2T=22.0526; d=4.0308
AREA=20.7623; I=90.6092
2T=26.7810; d=3.3289
AREA=102.2679; I=479.8930
2T=27.9401; d=3.1934
AREA=8.6550; I=117.4563
AVERAGE BACKGROUND = 152.3150
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE


1/14/
DIF 23 62596
LP 23 6/25/96
Cu 1.541845
INTENSITY (counts)
3000.0
2400.0
1800.0
1200.0
600.0
0.0
2T=20.8672; d=4.2570
AREA=19.9117; I=114.1004
2T=21.9472; d=4.0499
AREA=13.8935; I=77.1856
2T=26.6230; d=3.3483
AREA=137.5216; I=802.0589
AVERAGE BACKGROUND = 165.7385
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE

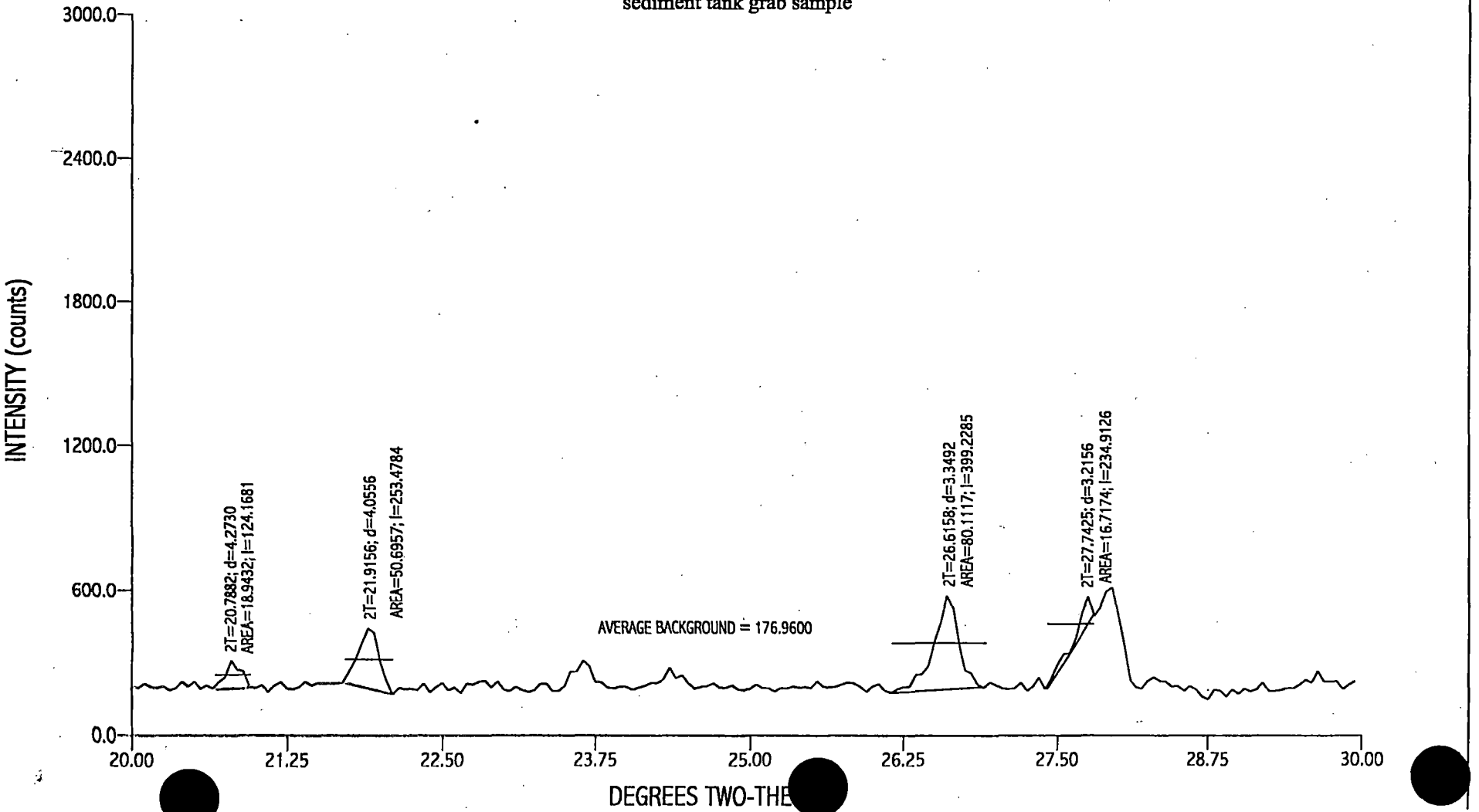
1/14/

DIF 123_6199

LP 123 6/1/99

sediment tank grab sample

Cu 1.541845

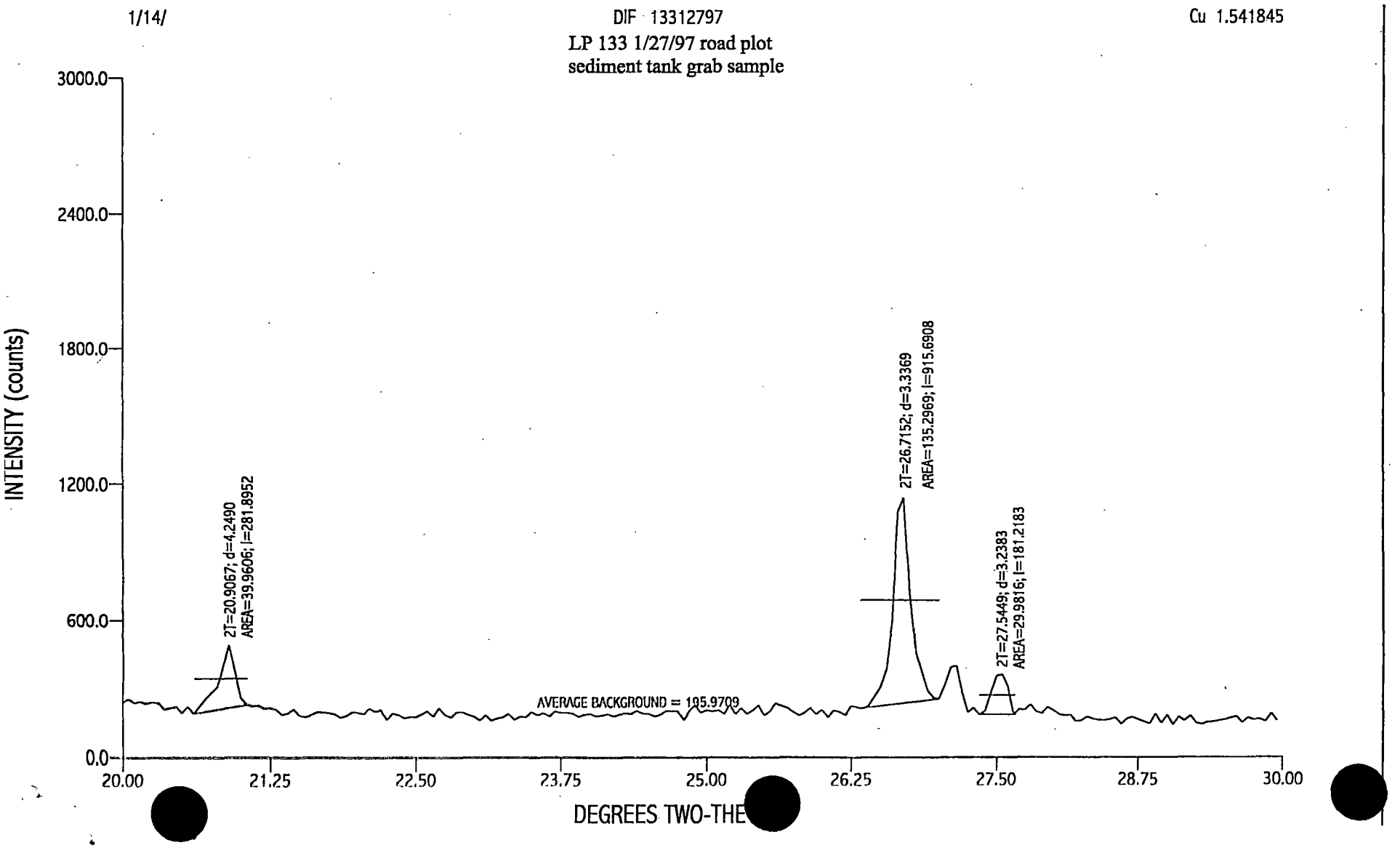


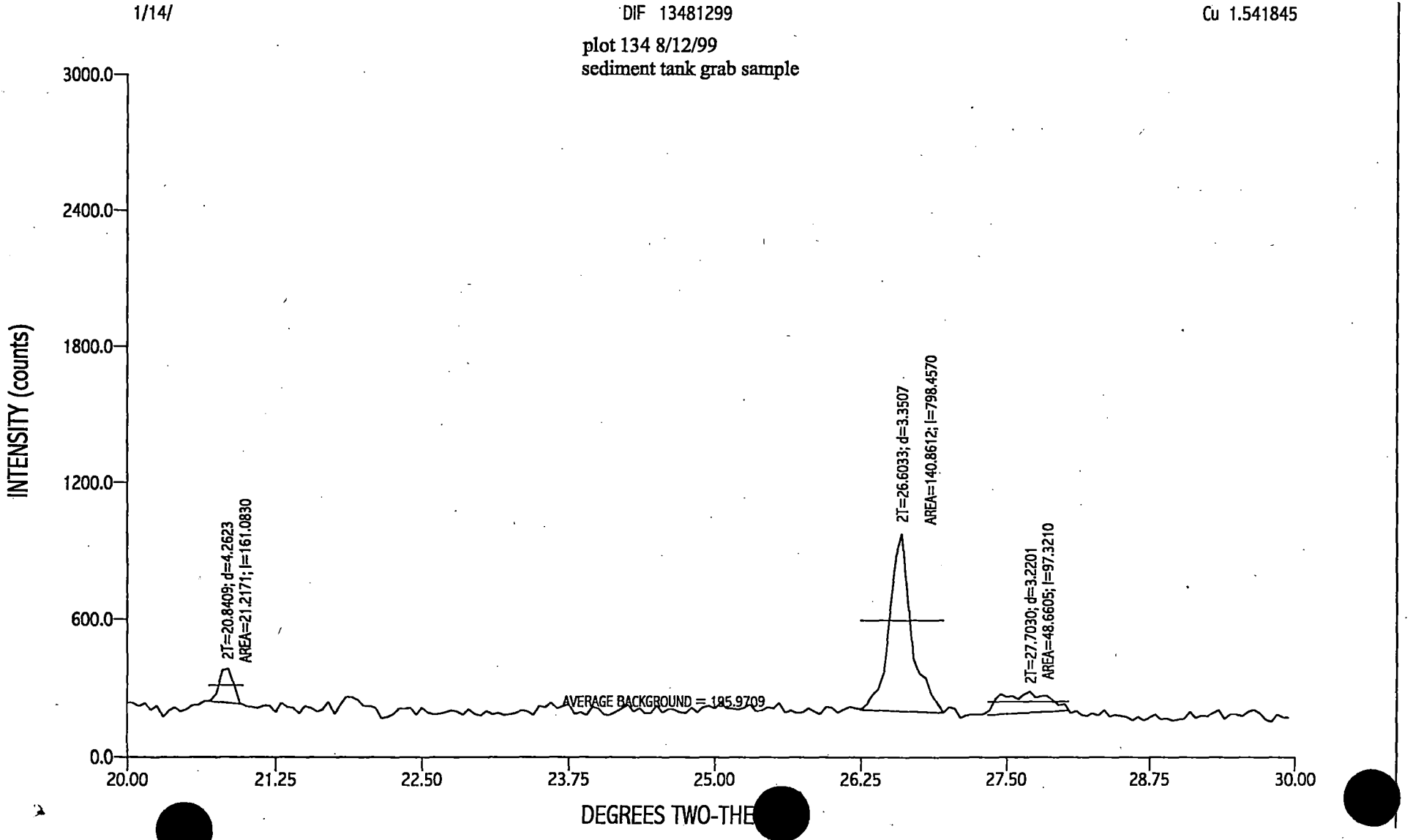
1/14/

DIF 13312797

Cu 1.541845

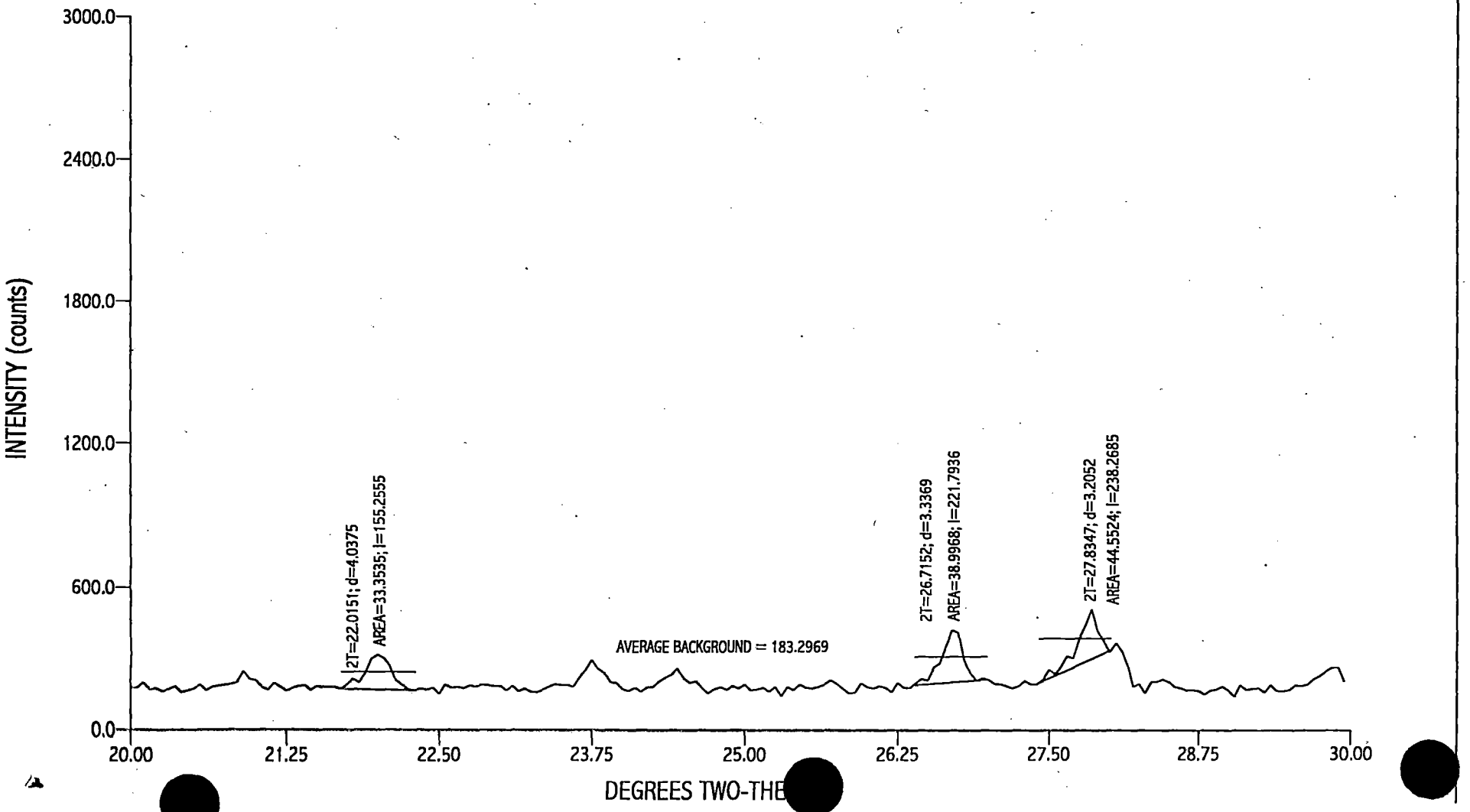
LP 133 1/27/97 road plot
sediment tank grab sample




1/14/
DIF 13481299
Cu 1.541845
plot 134 8/12/99
sediment tank grab sample
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.8409; d=4.2623
AREA=21.2171; I=161.0830
2T=26.6033; d=3.3507
AREA=140.8612; I=798.4570
2T=27.7030; d=3.2201
AREA=48.6605; I=97.3210
AVERAGE BACKGROUND = 185.9709
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE

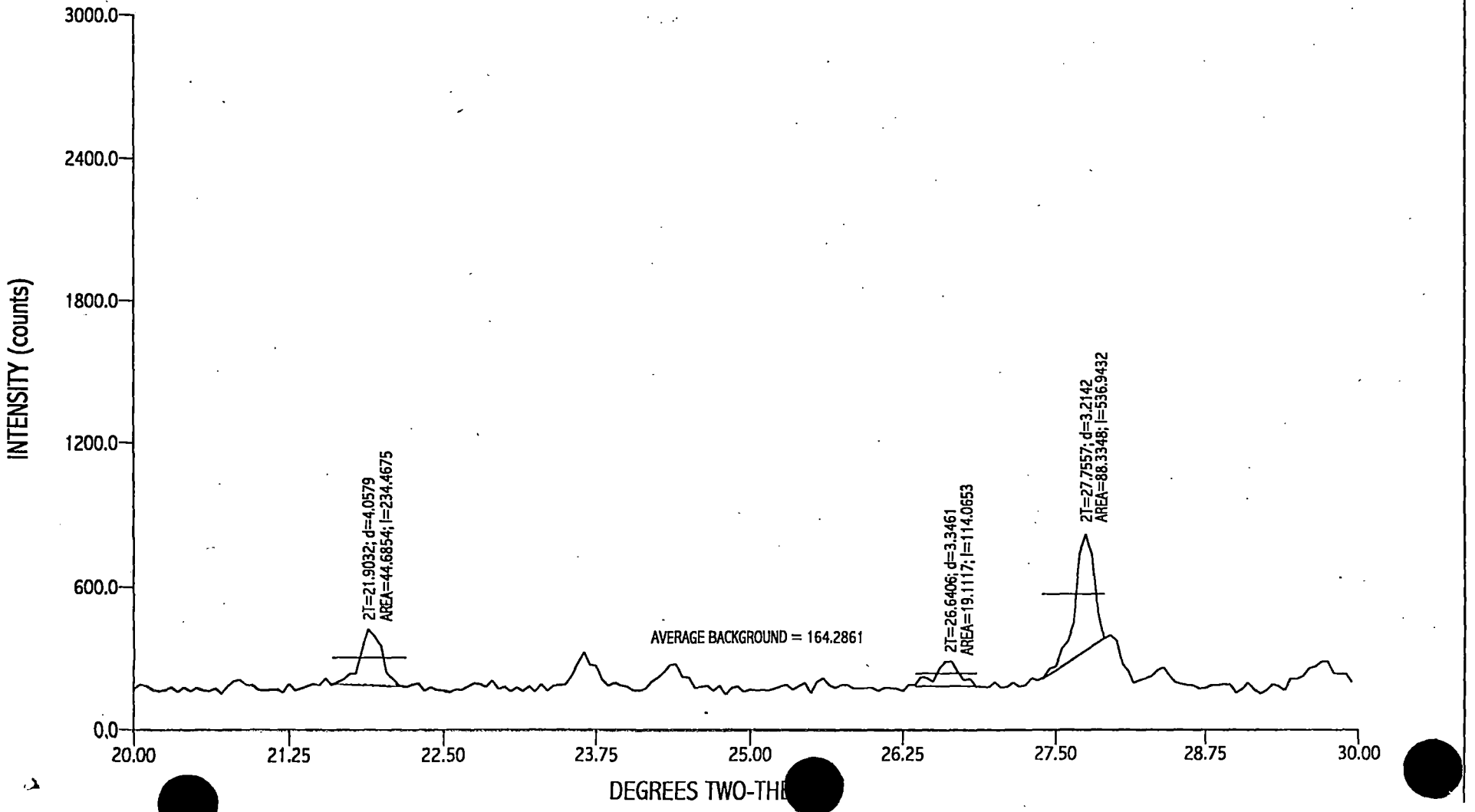
1/14/ DIF 11871499 Cu 1.541845

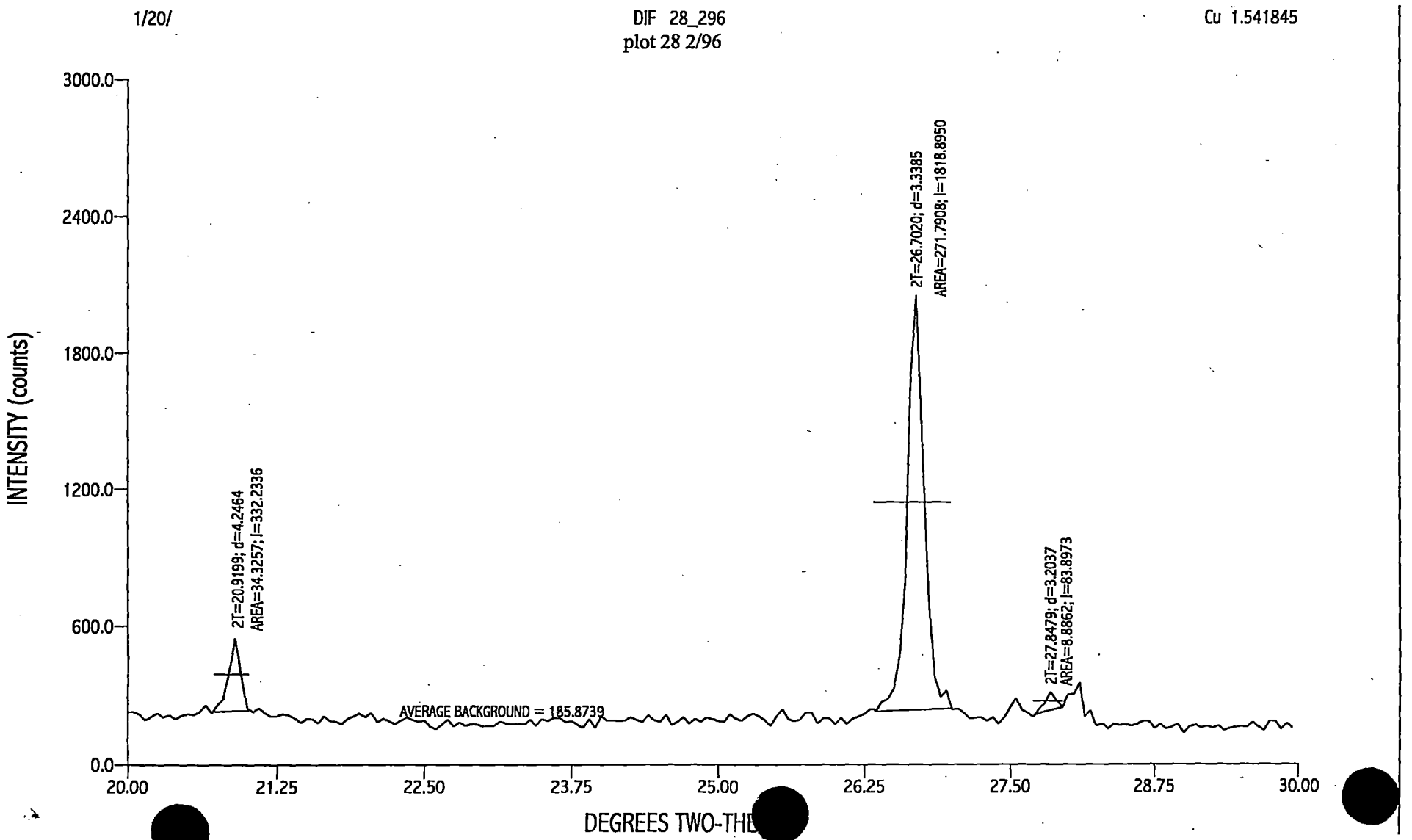
LP 118 7/14/99 sediment tank grab sample



1/14/ DIF 10371299 Cu 1.541845

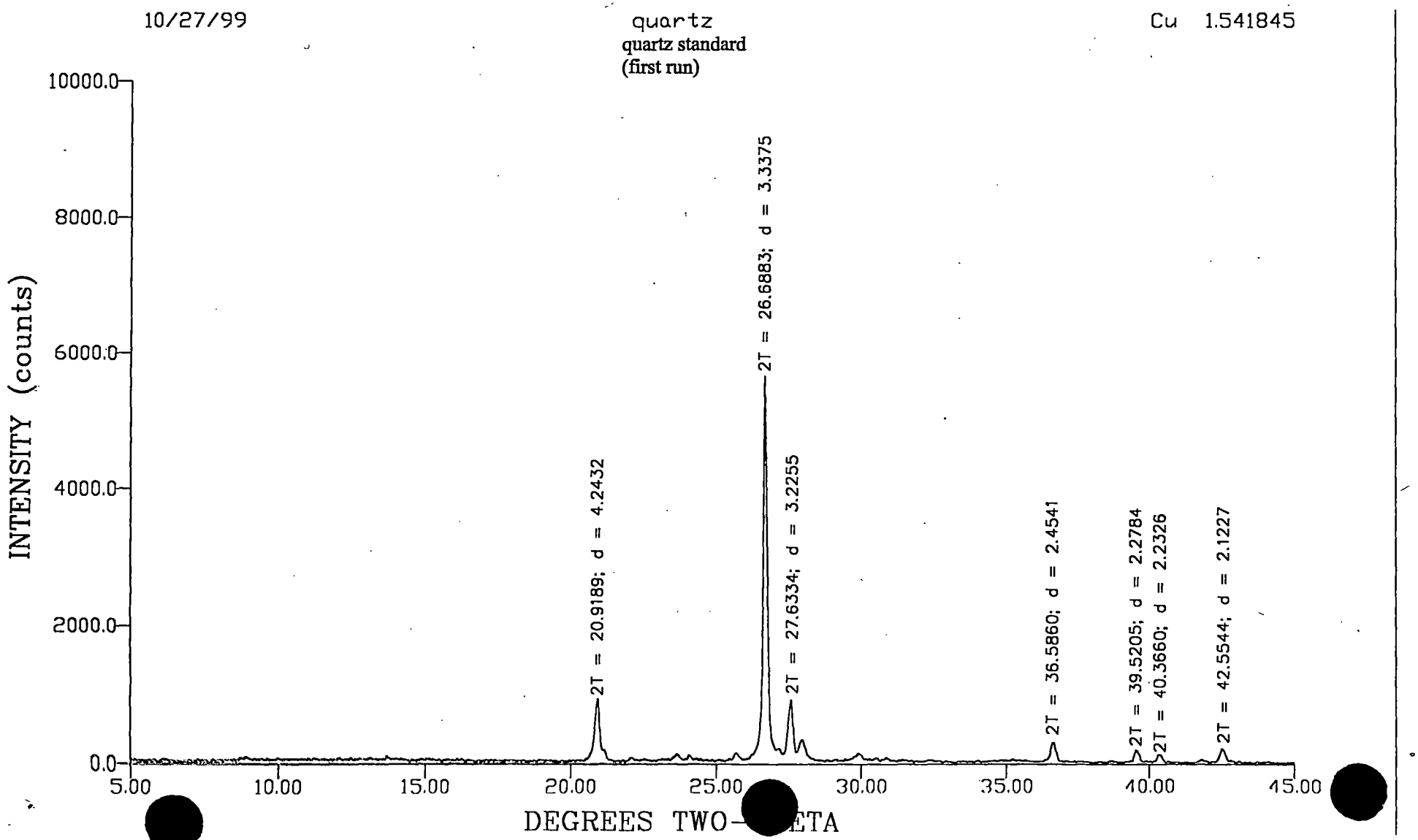
LP 103 7/12/99 sediment tank grab sample

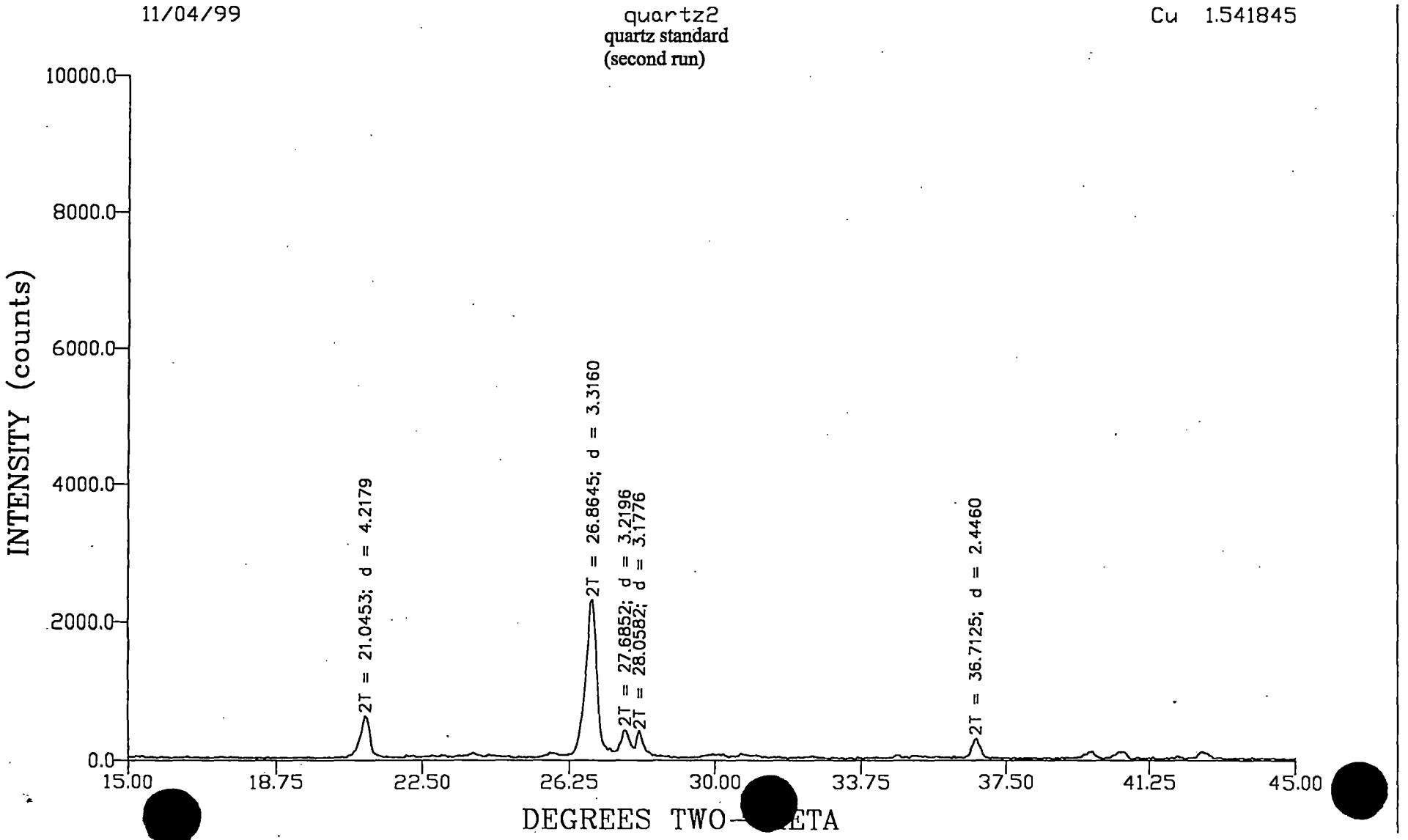


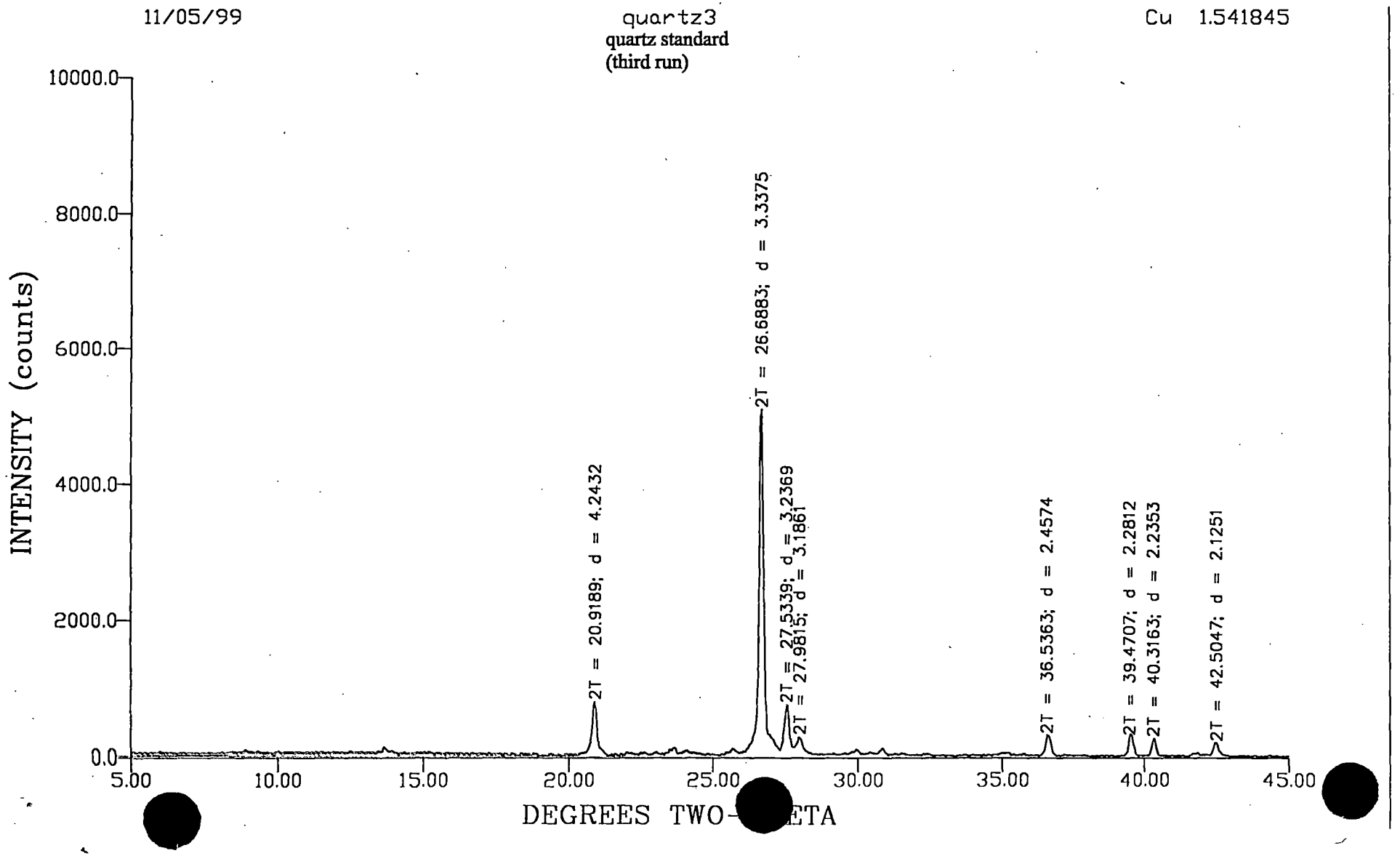

1/20/
DIF 28_296
plot 28 2/96
Cu 1.541845
3000.0
2400.0
1800.0
1200.0
600.0
0.0
INTENSITY (counts)
2T=20.9199; d=4.2464
AREA=34.3257; I=332.2336
2T=26.7020; d=3.3385
AREA=271.7908; I=1818.8950
2T=27.8479; d=3.2037
AREA=8.8862; I=83.8973
AVERAGE BACKGROUND = 185.8739
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-THE

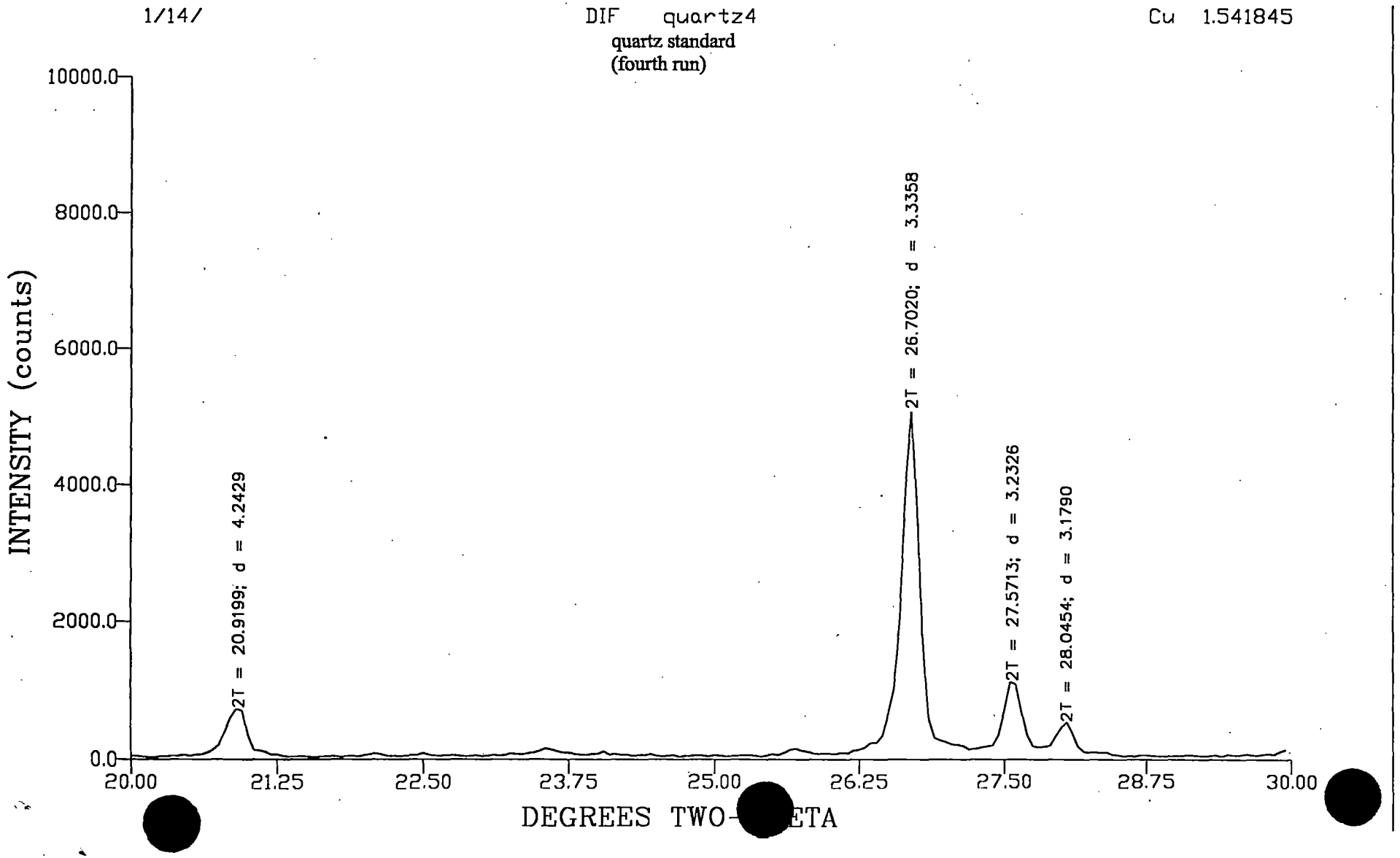
APPENDIX F:

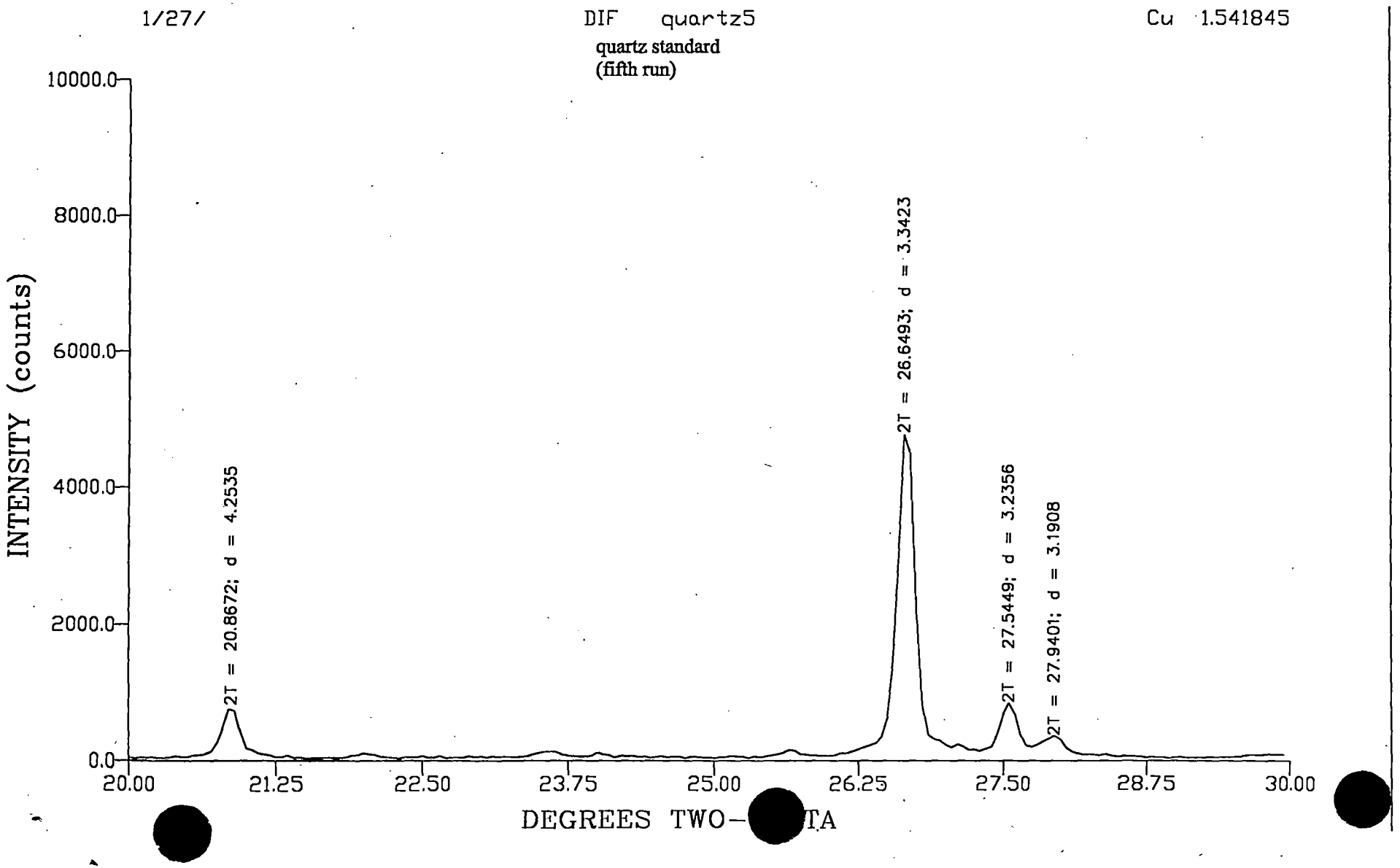
X-ray Diffraction Patterns for Quartz Standards


10/27/99
quartz
quartz standard
(first run)
Cu 1.541845
INTENSITY (counts)
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
DEGREES TWO-THETA
2T = 20.9189; d = 4.2432
2T = 26.6883; d = 3.3375
2T = 27.6334; d = 3.2255
2T = 36.5860; d = 2.4541
2T = 39.5205; d = 2.2784
2T = 40.3660; d = 2.2326
2T = 42.5544; d = 2.1227


11/04/99
quartz2
quartz standard
(second run)
Cu 1.541845
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
INTENSITY (counts)
2T = 21.0453; d = 4.2179
2T = 26.8645; d = 3.3160
2T = 27.6852; d = 3.2196
2T = 28.0582; d = 3.1776
2T = 36.7125; d = 2.4460
15.00
18.75
22.50
26.25
30.00
33.75
37.50
41.25
45.00
DEGREES TWO-THETA


11/05/99
quartz3
quartz standard
(third run)
Cu 1.541845
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
INTENSITY (counts)
2T = 20.9189; d = 4.2432
2T = 26.6883; d = 3.3375
2T = 27.5339; d = 3.2369
2T = 27.9815; d = 3.1861
2T = 36.5363; d = 2.4574
2T = 39.4707; d = 2.2812
2T = 40.3163; d = 2.2353
2T = 42.5047; d = 2.1251
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
DEGREES TWO-


1/14/
DIF quartz4
quartz standard
(fourth run)
Cu 1.541845
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
INTENSITY (counts)
2T = 20.9199; d = 4.2429
2T = 26.7020; d = 3.3358
2T = 27.5713; d = 3.2326
2T = 28.0454; d = 3.1790
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-


1/27/
DIF quartz5
Cu 1.541845
quartz standard
(fifth run)
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
INTENSITY (counts)
2T = 20.8672; d = 4.2535
2T = 26.6493; d = 3.3423
2T = 27.5449; d = 3.2356
2T = 27.9401; d = 3.1908
20.00
21.25
22.50
23.75
25.00
26.25
27.50
28.75
30.00
DEGREES TWO-